THE OBSERVER'S HANDBOOK

METEOROLOGICAL OFFICE

LONDON

1913.

Superseded

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METEOROLOGICAL OFFICE.

THE OBSERVER'S HANDBOOK.

APPROVED FOR THE USE OF METEOROLOGICAL OBSERVERS

BY

THE METEOROLOGICAL OFFICE,

THE ROYAL METEOROLOGICAL SOCIETY,

THE SCOTTISH METEOROLOGICAL SOCIETY,

THE BRITISH RAINFALL ORGANIZATION.

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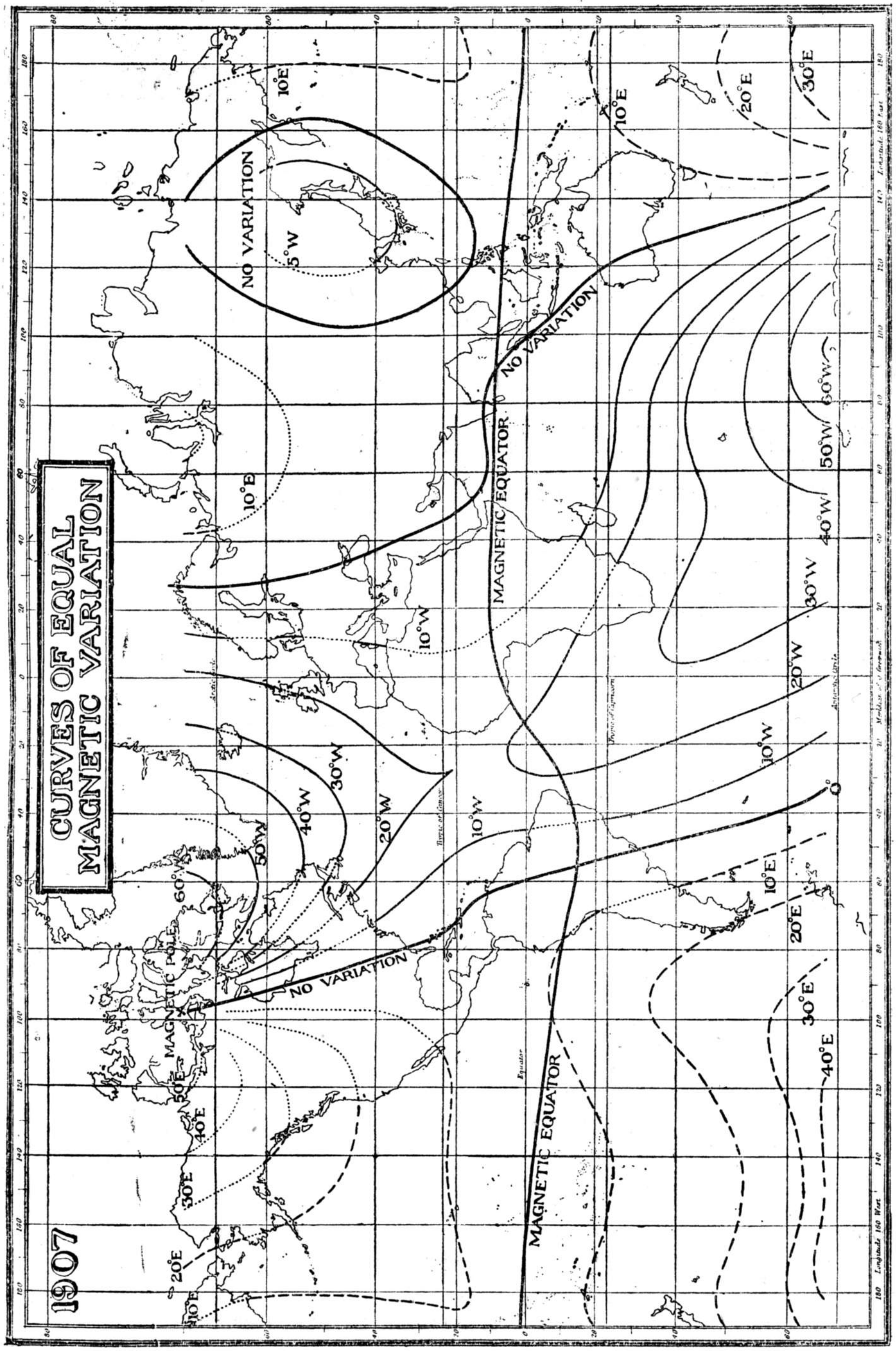

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The lines of no magnetic variation and the magnetic equator (line of no dip) have been thickened. Continuous lines indicate lines of equal deviation to the West of "True" North, broken lines indicate lines of equal deviation to the East of "True" North. The lines are shown dotted over the land.

PREFACE.

The "Observer's Handbook," in continuation of Dr. Scott's "Instructions in the use of Meteorological Instruments," which in its turn succeeded Sir H. James's "Instructions for taking Meteorological Observations" was originally issued in 1908. Its preparation was entrusted to Mr. R. G. K. Lempfert, who was at the time Superintendent of the Statistical Branch of the Office.

An endeavour was therein made to add precision to the non-instrumental observations by careful collation of the corresponding terms of different countries, by a new table of equivalents of the Beaufort scale and other results of recent researches in wind measurement, and by the introduction of a scale of fog intensity. With reference to the last it may be mentioned that in dealing with words which are in ordinary use, it has not been thought advisable to endeavour by meteorological definition to maintain distinctions that are not in accord with ordinary practice.

Illustrations of cloud forms were not included in the first issues. It was intended to issue separately a selection of the illustrations comprised within the new edition of the International Cloud Atlas which was then in the press. The Atlas has now been published and copies can be obtained from the Meteorological Office, price 10*s.*, post free. But it has not been found practicable to make a selection of the illustrations for this work. Meanwhile, Mr. G. A. Clarke, of the Aberdeen Observatory, has made a most interesting collection of photographs of cloud forms, including a number of series taken in rapid succession. From his collection a selection has been made for reproduction here and names according to the international classification have been assigned to them.

In the sections dealing with self-recording instruments endeavour has been made to secure accuracy by a careful specification of essential dimensions.

Throughout the book the necessity which every meteorologist feels for uniformity of practice has been kept in view. The decisions of the International Conferences have been followed* wherever they bore upon meteorological practice in this country.

* See Codex of Resolutions adopted at International Meteorological Meetings, 1872–1907, by G. Hellmann and H. H. Hildebrandsson. English Edition, published by Authority of the Meteorological Committee. M. O. 200. Price 1*s.* 3*d.*

(31279—24.) Wt. 17528—86. 500. 11/13. D & S. G. 30. Sch. 7. A 2

In the preface to the first issue over the date, February 28, 1908, I wrote :—

"The most grievous departure from uniformity of practice among "meteorologists, the use of different units of measurement in different "countries, still remains. The matter came before the Meteorological "Council in 1904, and I venture to print as an appendix to this "volume a memorandum approved by the Council at that time.

"The reality of the objection to the use of negative values for "temperature and the inconvenience of the millimetre as a practical "interval of pressure are, I feel sure, the chief obstacles in the way "of a common system. The tendency of all physical measurements "toward expression in absolute measure is based upon a sufficiently "sound principle to warrant my drawing attention to it once more."

Since that date the question of units has become an urgent one for the Office. The Meteorological Committee in their Report to the Lords Commissioners of H.M. Treasury for the year 1912–13, have signified their sanction of the use of *centibars* or *millibars* instead of inches for expressing pressure in British weather maps from May 1, 1914, and provision has already been made for replacing the traditional dial of the wheel or aneroid barometer with its 29·5 in. reading marked "change" by one in which the same position is simply marked 100. It has, therefore, become necessary to set out the position of affairs in this country as regards the question of units for meteorological work, and this has been done in this issue by an introductory memorandum on the extension of the C.G.S. system of units to meteorological measurements.

In 1909 it was arranged that an annual edition of the Handbook should be issued, and opportunity was then taken to obtain the approval of the volume by the Royal Meteorological Society, the Scottish Meteorological Society and the British Rainfall Organization for the use of observers connected with those institutions. Since Meteorological Science is entirely of a co-operative character and observations are only useful in so far as they are comparable with those made in other places or at other times it is clear that instructions in the use of instruments are only satisfactory in so far as they represent the general consensus of opinion as distinguished from the opinion of a single institution or individual. It is therefore an essential condition of progress that the arrangements for making and recording observations should be the subject of common agreement between the institutions responsible for the control of the various parts of the network of stations in this country.

The Observer's Handbook is intended to represent the results of the experience of all who are concerned with Meteorological Observations in connection with the Office, so that many persons in their

various ways contribute to its pages directly or indirectly. Suggestions for its improvement from those who use it are gladly welcomed. The compilation of these results and their incorporation in this issue have been entrusted to Mr. E. Gold, the Superintendent of the Statistical Division, as Editor, and to Mr. F. J. W. Whipple, Superintendent of the Instruments Division, as custodian of the instruments in use at the Office.

W. N. SHAW.
Director.

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Preliminary.

In the original edition of the *Observer's Handbook*, which appeared in 1908, reference was made to a *Memorandum on the Suggested Uniformity of Units for Meteorological Observations and Measurements* which was approved by the Meteorological Council in 1904. The suggestion therein put forward was that, in view of the wide-spread use of units based upon the Centimetre-Gramme-Second system for measurements in magnetism, electricity, and other sciences with which meteorology is closely allied, and of the objections based upon practical grounds to the arbitrary metric units in ordinary use, there was no reasonable stopping point for those who desired the universal adoption of a single system of units short of the C.G.S. system. The Memorandum indicated a selection of units based upon that system which would meet practical requirements.

Since that date rapid progress in the scientific investigation and the practical navigation of the air has brought the question of units into prominence, and other circumstances have combined therewith to make some action a practical necessity. Among these may be mentioned here the fact that meteorological messages are sent out daily from the Eiffel Tower, the German station at Norddeich, and the Admiralty station at Cleethorpes. It has been proposed to place this service on an international basis immediately and to issue a daily meteorological message from the Eiffel Tower for the use of ships at sea. The message issued at

present includes a number of barometer readings. The usefulness of the messages will be increased if the units employed are the same as those used aboardship for observing. On the threshold of a new departure, which may in time alter many of the details of the *Observer's Handbook*, it is desirable that these circumstances should be reviewed, and a statement given with regard to the units which have already in part been adopted as the expression of a general principle by the Meteorological Office.

Originally the circumstances were as follows :—A selection of arbitrary units comprising the inch of mercury, the Fahrenheit degree, a mile per hour (with a foot per second and a foot per minute as variants), an inch for rainfall, a foot for height, and a mile for distance (with a nautical mile and a degree as variants), were in use in all English-speaking countries for meteorological measurements, and were found to be for all the essential practical purposes of observing, tabulating and mapping, more convenient than the selection of equally arbitrary units comprising the millimetre of mercury, the centigrade degree, a metre per second (with a kilometre per hour as a variant), a millimetre for rainfall, a metre for height, a kilometre for distance (with a sea mile and a degree as variants), in use in all but the English-speaking countries. The disparity in use is not so great as might appear to those whose experience is confined to scientific literature or international assemblies, because the number of governments of which English is the official language is large, though they are widely separated, as a rule, by miles of sea, and many of them are not ordinarily represented in international assemblies. They, nevertheless, have decided opinions upon any subject which bears upon practical life as meteorology does ; and, altogether, when the sailors are counted in, there is a very large body of meteorological observers who are in favour of the customary inch-Fahrenheit units.

In referring to units of measurement, it is customary to speak about the metric "system" in contradistinction to the English want of system ; but, in meteorology, the metric measures are not more systematic than the British, for both are arbitrary. Where the metric system would have been really systematic—that is in geographical measurements, it has failed to establish itself on the decimal system. The metre as the tenth part of a second, the thousandth part of a minute, the hundred-thousandth part of a grade, and the ten-millionth part of the earth's quadrant, has some claim

to consideration ; but as an arbitrary length-standard, 111·1 of which make a geographical degree of 60 nautical miles, it makes only a feeble appeal to the reason ; and, if that were all, we might hope in time to convince the world of the greater practical utility of the inch and the Fahrenheit degree. For the latter, until the study of the upper air introduced a deluge of negative quantities, there was still a good deal to be said, for the time has long gone by when the freezing point and the boiling point of water were regarded as natural fixed points. As soon as elaborate definition becomes necessary, the naturalness of the unit disappears.

But when one comes to the *discussion* of meteorological observations, which consists eventually in their comparison with corresponding observations all over the world or with the *data* of other sciences, the question takes on an altogether different aspect. Every meteorologist who uses British units for his own observations, if he be engaged also in scientific discussion, must be familiar with the metric units. Physics, chemistry and all the other sciences which can be followed within the walls of laboratories, and are, therefore, the sciences taught to the young, use nothing else for technical quantities. All schools for boys or girls, all colleges and universities for men and women, although they speak English, apparently suppose that meteorological observers use metric units, for until they are faced with the exigencies of practice, they regard no other.

In electricity and magnetism the use of the C.G.S. system is universal. All experts in motor cars or in aviation are quite accustomed to the metric system, and, if one wishes to find out persons of intelligence to whom metric units are unfamiliar and repulsive, one has literally to think of special classes of engineers and meteorologists.

On the other hand, to the habitual practitioner in metric units, our useful and practical British units seem irrational and impossible and to publish meteorological papers in English without translating the figures—the language is curiously enough of less importance—is practically to restrict the publication to a very limited circle of readers. The learning of a new set of units is not really a very difficult matter and one easily becomes bi-lingual in that respect, just as one easily accommodates oneself to a new coinage upon passing a political frontier, but it does involve a definite effort to begin with and the necessity for that effort excites a good deal of resentment. There is, obviously, a class of

British readers who think they can understand the facts about the stratosphere better if they are expressed in British units, though, upon examination, the psychology of the opinion is rather recondite ; but there are quite as many on the other side who produce a variety of fantastic arguments to prove that the use of anybody else's units is irrational when they really mean that it is unfamiliar. The criticisms that are made on the one side or on the other about the change of practice, which would really be an old story in 12 months, remind one of the clamour for the restitution of our 11 days in 1752.

Special Units for Aerology.

To the circumstances referred to as original, others have now to be added. The question of the publication in the official Reports of British data for the upper air in 1906 presented peculiar difficulties. No one unfamiliar with continental units was in the least likely to read them for the purposes of study for which they were published. At the same time, as regards temperature, the readings at the highest levels, which are most important, are frequently between $-20°$ and $-60°$, that is to say, in the region in which the figures might equally well belong to the centigrade or to the Fahrenheit scale. In what may be called a Fahrenheit country, it is not fair to print figures that may easily be confused with the ordinary scale but are not of it. Moreover, for the upper air all the important figures are those of temperatures below the freezing point, so that if the centigrade scale is used nearly all the arithmetic is topsy-turvy.

The pressures at these high levels introduce a new conception to the reader. No one is familiar with a barometric pressure of say 2 in. or 6 in., and to encourage the familiarity of practice in units that would certainly be found unserviceable whenever the actual quantities came to be used in calculations seemed needlessly cruel.

Here, again, fortune came in with the consideration that the standard atmospheric pressure at sea level is 1·013 megadynes per square centimetre, and therefore so nearly one million C.G.S. units, *i.e.*, 100 centibars, or 1,000 millibars, that for everything except refined numerical calculations the value of the pressure in bars or megadynes per square centimetre is the decimal fraction of the sea level pressure, and in dealing with results for the

upper air that fraction has to be calculated mentally until the reader is, by long experience, familiar with actual figures, and for such familiarity any units will serve. Consequently it was decided, after consultation, to print the British values for pressure in the upper air in the Weekly Weather Report in megadynes per square centimetre and to express temperatures in centigrade degrees measured from the computed absolute zero of the gas thermometer or 273° below the standard freezing point.

In 1908 Professor McAdie, of California, proposed that pressures should be expressed as decimal fractions of a standard atmosphere, and Professor Köppen, at the meeting at Monaco of the Commission for Scientific Aeronautics, proposed that the C.G.S. atmosphere of a megadyne per square centimetre should be the basis of the numerical expression of pressure for the results of the investigation of the upper air. Professor Bjerknes made a similar proposal, and the question was referred to the International Meteorological Committee. Before the Committee met, the question was considered by a Board appointed by the chief of the United States Weather Bureau, which drew up a report generally conservative as regards present practice, but containing the following qualification as regards pressure: "but it (the Board) recognises that the C.G.S. system of absolute units is peculiarly appropriate to the publication of aerological observations, and commends its use in such work."[1] The International Meteorological Committee came to the conclusion that the time had not yet arrived for a final opinion to be given on the matter, but, according to the official report,[2] it appeared from the discussions that the suggested absolute measurement for pressure data was appropriate for theoretical investigations, but it would be premature as yet to express all pressure data in these units.

When the subject has been under discussion, the weight of opinion has always supported the view that units of the C.G.S. system with temperatures in the absolute scale are suitable for theoretical work, because they simplify the numerical calculations that are otherwise extremely laborious, and this view is very clearly enunciated by the publication by the Carnegie Institution of Washington of two volumes on "Dynamical Meteorology and Hydrography," by Professor V. Bjerknes, in which the outlines of a great structure of dynamical meteorology are laid down on the foundations of

[1] M.O. 208, p. 76. [2] M.O. 208, p. 18.

(1) simultaneity of observation, (2) pressure as an independent variable, and (3) tabulations in absolute units.

Up to the present time the results of the study of the upper air have been chiefly obtained by the geographical method of mapping, for which any units are suitable, provided the same are used for all places ; but to anyone who looks into the matter it will be clear that most of the results that can be obtained by the geographical method have been already won, whereas for further progress such considerations as those of density claim attention, and for these absolute units are specially suitable.

Consequently, at a largely attended meeting of the Commission for Scientific Aeronautics in Vienna in May, 1912, proposals by Professor Bjerknes on the lines already indicated were passed with only two dissentients, but it was resolved that the use of C.G.S. units should only come into operation for the international publication of the results for the upper air when it had received the sanction of the International Meteorological Committee. Professor Köppen regards the proposal as admissible only if the English-speaking meteorologists regard it as a first step in the adoption of the millibar in ordinary practice. It would be generally admitted that the introduction of a third unit is only justifiable as a step in the direction of uniformity.

Extension of the System to Meteorology.

So far, the opinions of other nationalities have been mainly cited, but in this country further steps have been taken towards a final decision upon the question. In July, 1910, the Meteorological Office took over from the National Physical Laboratory the administration of the Kew and Eskdale Observatories, and became responsible for work in magnetism, atmospheric electricity, and other branches of geophysical study, with the advice of the Gassiot Committee, a body appointed by the Royal Society primarily to carry out the provisions of the deed of trust of a fund of £10,000, the gift of the late Mr. J. P. Gassiot for the maintenance of physical experiments at Kew Observatory. The committee includes the most prominent physicists of this country who are interested in the work of a physical observatory. Under the partnership which was operative before the transfer, the meteorological work was controlled by the Meteorological Office and the rest of the work of the observatories by the

National Physical Laboratory, and it was not thought unreasonable to publish the results for the two sides in units which were entirely out of harmony; but when the Office became responsible for the publications of all the results, the co-ordination of the work inevitably led to the question of the co-ordination of the units. The Gassiot Committee gave its opinion in the following resolutions :—

"1. That in the opinion of the Gassiot Committee of the Royal Society it is essential that all meteorological returns compiled for international use should be expressed in terms of an international system of units founded on the metric system."

"2. That a system in which the measure of barometric pressure is expressed in megadynes per square centimetre and of temperatures in absolute degrees Centigrade would be a satisfactory one."

In consequence, the results of the work of the Observatories from January 1911 have been published in C.G.S. units, and for the year 1912 the daily observations at the 13 meteorological stations of the Second Order, which are similar in form to the meteorological results of the Observatories in the Geophysical Journal, have been brought into the same form.

This action brings us to the parting of the ways, and we must now either retrace our steps, or bring the ordinary meteorological instruments gradually into line with the new departure, or regard the work of observatories and second order stations as practically independent of the work of the Daily Weather Service, and the Daily Weather Service as unconcerned with dynamical and physical reasoning.

The third course must be regarded as out of the question, and consequently the time has come to review the question of the suitability of the units of the C.G.S. system for the work of the observatories on the one hand and the work of the daily study of the weather on the other.

Meteorological observations in relation to Dynamics and Physics.

Let us summarise the position of meteorological observations in this country. We are using instruments giving measurements which are certainly convenient for our

immediate purposes, but they are not used in educational institutions for the teaching of those sciences which are indispensable for the study of dynamical meteorology, and all students of meteorology who wish to understand questions of dynamics, humidity, density, electricity, magnetism will find themselves debarred from reading the best textbooks on those subjects until they have acquired a knowledge of the units of measurement which the professional exponents of those subjects use, and thereafter they will find that in order to use their observations for any purpose, except a geographical one, they will have to transpose all their measurements, and a transposition will be necessary even for geographical work which goes beyond the confines of the kingdom. It is impossible to estimate the depressing effect of these circumstances upon the study of meteorology in the various states of the British Empire. In all of them there is a lamentable dissociation of meteorology from the study of dynamics and physics which is largely attributable to that cause. The dissociation has been continued for the past 50 years during which the C.G.S. system has gradually established itself as an international system for electricity and magnetism. We cannot hope that in the future the practical convenience of our ordinary units will appeal successfully to our continental colleagues and our own educational authorities, and, consequently, we ought to face the disagreeable consequences of a change of units and corresponding changes in the graduation of our instruments unless the practical consequences are so serious as to be overwhelming.

At the present time weather information is exchanged between the various countries of Europe, including the United Kingdom, by means of coded figures. There is a separate code for continental reports and British reports. The result of recent deliberations upon the codes for the international exchange has been to suggest that only two figures should be allowed in future to express rainfall in the British code instead of three figures as at present. The only practicable plan of carrying out this suggestion is to divide the British readings (now given in hundredths of an inch) by 4 ; that is, to express the rainfall in millimetres. This would necessitate replacing the present raingauge-glasses at the telegraphic stations, which are now graduated to hundredths of an inch, by glasses graduated in millimetres, and thus if the proposal is approved, a beginning will have been made in the change of instrumental equipment.

Continental Metric Units.

The next question is whether, if we change our units, we should simply fall into line with continental countries and use the arbitrary units to which they are accustomed, or follow the lead of our electrical and magnetic colleagues and adopt the C.G.S. units in the hope that some day our continental colleagues will do the same, and thereby secure a universal system. Between these alternatives two opinions are hardly possible. Apart from the cogent advocacy of Professor Bjerknes, representing presumably in such matters the Carnegie Institution, we have the general opinion that C.G.S. units are most suitable for theoretical work. But theory stands for the head-light of every science and shows the direction in which the science should travel. What is theory to-day becomes practice to-morrow, and practice does well to follow the path that theory indicates. If the C.G.S. units are really suitable for theoretical work they are undoubtedly the units of the future.

Besides, there are strong practical reasons against the adoption of the arbitrary units used on the Continent. The issue turns largely upon the use of thermometers and barometers. For wind velocity we have been accustomed for years to use numbers which we know are 25 per cent. wrong, so that we cannot be said to be hardened in the use of "miles" per hour, because the conventional "mile" which we used until 1906 and is still used apparently in some observatories at home and in the British Dominions beyond the seas, is about three-quarters of the statute mile; for rainfall the fact that 4 "points" = 1 mm. makes things easy. Let us consider, therefore, our thermometers and barometers. The centigrade scale with its zero at the freezing point of water is practically impossible for us. A scale of temperatures including positive and negative signs is dangerous for the observer, troublesome for the computer, awkward for the printer, misleading for the reader, and therefore altogether unsuitable. No country like ours, which is mercifully free from the troubles of temperature signs, would ever willingly adopt them. This argument may not appeal to Americans and Canadians with such force as it does to us, because they have many negative temperatures already, but for us it is unnecessary to go further.

As to barometers, apart from its being arbitrary like our own inch, we find the millimetre of mercury at 0° C. in latitude 45° an inconvenient unit for our daily work. Conti-

nental countries are accustomed to draw isobars for every five millimetres. We could not work with so large an interval, and when we consider that all the evidence of modern meteorology goes to emphasise the importance of the representation on the map of the minor fluctuations of atmospheric pressure as being associated with the recognised phenomena of weather, it will be agreed that isobars with 5 mm. or ·2 in. intervals are not enough for the detailed working chart of to-day. The tenth of an inch which we use, though it is hardly close enough for our present purposes, does not give whole millimetres but 2·5 mm. steps. And if one plots to 2 mm. one misses the 5 mm. line which we can use to-day to compare our maps with those of other countries.

When to these practical objections we add the weight of the advice of the Gassiot Committee and bear in mind the action that has been taken thereon, there is little more to be said. We can only decide in favour of the C.G.S. units.

Practical arrangements for the change to C.G.S. Units.

It remains to consider what the practical arrangements for the change should be. The difficulty of the change of units and corresponding change of graduations of instruments is probably liable to exaggeration. So far as present observers are concerned it is only a question of familiarity, and probably a fortnight's experience would be sufficient to make a new instrument quite familiar and acceptable, especially if it saved labour. To all men of science and to most observers the readings are only conventional figures until they have been properly reduced and corrected, and the fact that reduction and correction are always necessary makes it possible to carry out the change of units with little trouble by the use of a suitable table of corrections, and thus to obviate the necessity for altering *all at once* the instruments now in use.

Incidental advantages of a Rational Measure of Pressure.

It would appear from some of the contributions to the controversy on this subject which has arisen over the proposals of Professor Bjerknes, that even an accomplished

meteorologist may be misled by the use of familiar language into thinking that one reads directly on a barometer millimetres of mercury at 0° C. in latitude 45°, but it is not really so. What one reads on a barometer in the ordinary way is not a millimetre, and the mercury is not at 0° C. nor at 45° latitude; we read an arbitrary something from which the pressure can be computed by the introduction of a number of reductions and corrections.

This fact is a matter of great importance, not merely for expert meterologists but for all observers, and the introduction of absolute units brings out the fact in a most striking and useful way. Accustomed thereto by long habit, one is not ashamed to display a barometer showing apparently graduations in inches though one knows that they are not inches and forgets that the observer who uses the apparatus may be misled by our carelessness, and omit to take account of the attached thermometer and the correction for latitude; but one cannot display a mercury barometer showing directly a graduation in *millibars*. The casual printing in the observatory results for 1911 of "1 in. mercury = 33·86 mbar." at once excited remark, and quite justly. We must, therefore, draw a clear distinction between what is read as an approximate length of mercury column and what is finally deduced as the pressure in absolute units (millibars), and the attention which is thus drawn to the necessity will make for increased accuracy in the measurements because not even the most uninstructed observer can fail to notice that when pressure is wanted the simple reading of the mercury does not give it. It appears that we must have a name for the empirical graduation as distinguished from the pressure deduced therefrom. The name of "baromil" has been suggested, and has been accepted as short and sufficiently expressive. It permits of the amplification "dibaromil" to indicate an empirical unit of the most convenient size for practical use.

For thermometers we are already using for certain purposes instruments graduated in centigrade degrees from 273° below the freezing point, and it is probable that they will be gradually introduced into ordinary practice.

In order to put before the reader the units of graduation which are thus contemplated and their relation to other units, the following list of meteorological units on the C.G.S. system has been drawn up.

The C.G.S. System of Meteorological Units.

The C.G.S. system of units now used universally for electrical and magnetic measurements is based upon the metric system.

In the metric system the multiplication of the unit by 10, 100, 1,000, 1,000,000 is indicated by the prefixes deka, hecto, kilo, mega, and the 10th, 100th, 1,000th, 1,000,000th part is indicated by the prefixes deci, centi, milli, and micro.

Primary Units.

Length.—The centimetre is one-hundredth of a metre, the unit of length from which the name of the metric system is derived.

1 cm. = ·0328 ft. = ·394 in.

The metre was originally intended as a geographical unit. The quadrant was divided into 100 grades instead of 90^c, a grade into 100 minutes and the minute into 100 seconds instead of the usual 60 parts in each case. The metre was taken as one-tenth of the centesimal second, *i.e.*, one ten-millionth of the earth's quadrant. But while the metre has survived, the proposed decimalisation of angles has not been adopted, and now only appears in the introductory chapters of books on trigonometry. From some points of view this is much to be regretted. The practice of using decimals has become very common, and it is convenient to use the number of decimal places as indicating the accuracy of measurement; but decimals go by tenths and not by sixtieths, so that one may measure angles with an accuracy of the tenth of a degree, but yet not to minutes and so on. Accordingly we find angular measures given in degrees and decimals, or in degrees, minutes and decimals, or in degrees, minutes, seconds and decimals according to the accuracy arrived at; meanwhile on the earth's surface 90° of arc represent approximately 10,000 kilometres or a degree of arc of 60 nautical miles = 111·1 kilometres. For measurements of distance on maps the nautical mile is the most convenient.

Mass.—The gramme is the metric unit of mass, and was originally intended to be the mass of a cubic centimetre of water at the freezing point. It approximates to that specification very closely. It is the thousandth part of the standard "kilogramme" of the International Bureau of Weights and Measures.

1 gramme = ·00220 lb. = 15·4 grs.

Time.—The second is a universal unit of time. There are 86,400 seconds ($60 \times 60 \times 24$) in the mean solar day by which "mean time" clocks are set and rated.

Area.—The unit of area in the C.G.S. system is the square centimetre.

$$1 \text{ cm.}^2 = \cdot 00108 \text{ sq. ft.} = \cdot 155 \text{ sq. in.}$$

Volume.—The unit of volume is the cubic centimetre.

$$1 \text{ c. c.} = \cdot 000035 \text{ c. ft.} = \cdot 061 \text{ c. in.}$$

Density.—The density of a substance in the C.G.S. system is the mass in grammes of a cubic centimetre of the substance. The unit density is one gramme per cubic centimetre. In the C.G.S. system the density of a substance is numerically the same as the specific gravity of the substance.

Velocity.—The unit of velocity in the C.G.S. system is the velocity of a centimetre per second.

$$1 \text{ cm. per sec.} = \cdot 0328 \text{ ft. per sec.} = \cdot 0224 \text{ miles per hour.}$$

Acceleration.—The unit of acceleration in the C.G.S. system is the acceleration of 1 unit of velocity per second, or 1 centimetre per second per second.

$$1 \text{ cm. per sec. per sec.} = \cdot 0328 \text{ ft. per sec. per sec.}$$

Force.—The unit of force in the C.G.S. system is the force which produces an acceleration of 1 centimetre per second per second in a mass of 1 gramme. It is called a dyne.

$$1 \text{ dyne} = \cdot 0000722 \text{ poundals} = 2 \cdot 25 \times 10^{-6} \text{ lb. in lat. } 45^\circ.$$

The numerical expression of the force acting upon any mass in the C.G.S. system is the product of the number of grammes which it "weighs," and the number expressing the acceleration which the force produces if allowed to act undisturbed by the other forces.

At sea level in latitude $49\frac{1}{2}^\circ$ the acceleration of gravity upon any falling body is 981 centimetres per second per second, hence the force of gravity upon the mass of a gramme is 981 dynes. This is the weight of a gramme. The reader will notice a curious confusion here ; one uses a balance to "weigh" a body, in reality to find its mass. The operation is only a part of the finding of its weight.

Pressure.—The unit of pressure in the C.G.S. system is a dyne per square centimetre.

1 bar, barye or megadyne per sq. cm. = 67,390 poundals per sq. ft.

Temperature.—The practical measure of temperature is so chosen that the volume of a mass of gas at constant pressure, or the pressure of a mass of gas at constant volume, is proportional to the temperature. It is the temperature on the centigrade scale increased by 273.

Practical Units.

For practical electrical and magnetic measurements certain multiples or sub-multiples of the fundamental C.G.S. units are adopted, and following the same lines with a view to practical meteorological measurement, we arrive at the following :—

The accepted normal pressure of the atmosphere or "standard atmosphere" is that of a column of mercury 76 centimetres high at the freezing point of water under the conditions as to gravitation which are to be found in latitude 45° N. or S. ; for other latitudes a small correction is necessary to allow for the difference of gravity. This pressure of a standard atmosphere is 1,013,193 dynes per square centimetre, or approximately 1·013 megadynes per square centimetre.

The practical unit of atmospheric pressure in the C.G.S. system is the megadyne per square centimetre, which may be called the "C.G.S. atmosphere." It is equivalent to a pressure of 750·1 millimetres of mercury at the freezing point of water in latitude 45° and is the normal air pressure at 106 metres above sea level. The name of "bar" or "barye" was agreed upon for this unit at the Conference of Physicists in Paris in 1900. The unit employed for tabulation is the millibar or ·001 of the C.G.S. unit.

The practical unit of rainfall measurement is the millimetre of rain, one tenth of the C.G.S. unit.

The practical unit of wind velocity is the metre per second, 100 times the C.G.S. unit of velocity.

The practical unit for the measurement of wind force is the kilodyne, the area exposed to the wind being stated.

The practical unit for wind pressure is the millibar, but the wind force is not exactly proportional to the area.

A brief account of some other units necessary for the study of dynamical and thermal problems connected with the atmosphere may be added.

Potential.—The study of the dynamics of the atmosphere introduces the conception of the energy of air masses at high levels. The energy of a mass of m grammes raised to a height h centimetres is $m\,g\,h$, where g is the mean value of the acceleration of gravity for the stretch between the ground and the height h. The numerical value of the acceleration of gravity is slightly different for different latitudes and for different levels. Its value at sea level in latitude 45 is 980·617 cm/sec^2.

The energy $m\,g\,h$ of a mass m is expressed in C.G.S. units of energy which are called ergs. If the energy expends itself in producing a velocity v, we have the relation $\frac{1}{2}\,m\,v^2 = m\,g\,h$. Potential is the name given to the energy which unit mass possesses in virtue of its position. If the energy is due to "height," *i.e.* to the force of gravitation, the energy of unit mass is $g\,h$ and we may call it *geopotential*. To find the geopotential for any position we must know how the gravitative acceleration varies and be able to deal with its variations. That is a separate study and we must borrow the results.

Mr. Whipple has suggested the name *leometre* for a practical unit of geopotential, consisting of 10^5 ergs per gramme. In that case a geopotential of 1 leometre would represent the potential energy of one gramme at a height of 1,000/981 metres, and would therefore represent what Professor Bjerknes calls a "dynamic metre." The geopotential for any position in the atmosphere would numerically represent the height in metres with an addition of about 2 per cent.

Radiation.—The measurement of solar and terrestrial radiation is a matter of increasing importance in meteorology. What is measured is the amount of mechanical or thermal energy absorbed from the sun or given out by a terrestrial object. It has been customary to express the measure of radiation in terms of the number of grammes of water which can be raised in temperature through 1° C. in one minute by the absorption of the radiation, and the unit in general use is therefore a gramme-calorie per square centimetre per minute. The gramme-calorie represents a known amount of energy which can be expressed in ergs, the recognised C.G.S. units of energy. The practical unit employed for measurement of energy in electrical work is the *joule*, which is 10^7 ergs. Equally well solar radiation can be measured by the energy absorbed in a measured interval and its intensity by the number of joules of energy absorbed per square centimetre per second, and the name given to the unit employed for that purpose in electrical measurements is the watt. It is the amount of energy required to maintain a current of one ampere in a resistance of one ohm.

These units belonging to the C.G.S. system are more suitable for the measurement of radiation for meteorological purposes than the arbitrary unit of a gramme-calorie per minute, because they bring the measurements of the solar energy into direct relation with other forms of energy.

The sheets for the records of solar radiation by the Callendar recorder used in the Meteorological Office are now ruled to give the intensity of sunshine in milliwatts, and the total amount of energy received between sunrise and sunset in joules. The results obtained in these units for solar radiation at South Kensington have been published in the Daily Weather Report since 1st January, 1913.

The following references may be found useful by those who wish to follow the historical development of the question of units for meteorological measurements :—

1888. Report of the British Association for the Advancement of Science. Report of the Units Committee of Section A recommending the name "barad" for one dyne per square centimetre.

1900. International Congress of Physicists at Paris. Report by M Guillaume proposing the name "barye" for the megadyne per square centimetre.

1902. Sandström and Helland-Hansen. Report on Norwegian Fishery and Marine Investigations, Vol. II.

1904. Report by a Committee to the Council of the British Association.

1906–7. Bulletin Trimestriel du Conseil permanent international pour l'exploration de la mer. Knudsen makes use of decibars and dynamic metres.

1906–8. Bjerknes and Sandström, in the Beiträge zur Physik der freien Atmosphäre, Vol. II., use the "bar" and its sub-multiples.

1908. McAdie. U.S. Monthly Weather Review.

1909. Weekly Weather Report. C.G.S. units used for the British results of the investigation of the upper air.

1909. Köppen. Meteorologische Zeitschrift, p. 198.

1909. Gold and Harwood. Report to the British Association on the Investigation of the Upper Air, in which absolute temperatures are used.

1910–11. Bjerknes, in Dynamic Meteorology and Hydrography (Carnegie Institution of Washington), introduces a scheme of computation on the C.G.S. system with tables.

1912. Sitzungsberichte und Vorträge der siebenten Versammlung der internationalen Commission für Wissenschaftliche Luftschiff-fahrt, Wien, Resolutions 6, 7, 8. Trabert. Meteorologische Zeitschrift, p. 179. Mill, H. R. Symons's Meteorological Magazine, p. 401. Bjerknes. Meteorologische Zeitschrift, p. 576.

1913. Bjerknes. Meteorologische Zeitschrift, p. 67. International Meteorological Committee. Report of the Meeting at Rome.

THE OBSERVER'S HANDBOOK.

PART I.

§ 1. CLASSIFICATION OF STATIONS.

The classification of Meteorological Stations is guided by resolutions of the International Congress of Meteorologists which assembled at Vienna in 1873. It is based on the scheme of observations to be taken. Three orders of stations are defined, under the following headings :—

(1.) **First Order Stations of the International Classification—Normal Meteorological Observatories :** at which continuous records or hourly readings of pressure, temperature, wind, sunshine and rain, with eye-observations at fixed hours of the amount, form and motion of clouds and notes on the weather, are taken.

(2.) **Second Order Stations of the International Classification—Normal Climatological Stations:** at which are recorded daily, at two fixed hours at least, observations of pressure, temperature (dry and wet bulb), wind, cloud and weather, with the daily maxima and minima of temperature, the daily rainfall and remarks on the weather. At some stations the duration of bright sunshine is also registered.

(3.) **Third Order Stations of the International Classification—Auxiliary Climatological Stations :** at which the observations are of the same kind as at the Normal Climatological Stations, but (*a*) less full, or (*b*) taken once a day only, or (*c*) taken at other than the recognised hours.

* The numbering of the pages in Arabic numerals begins with this page. There are no pages numbered 1–6.

The following combinations of hours of observation were recommended by the Meteorological Congress of Vienna* as suitable for adoption at Normal Climatological Stations :—

a.m.	p.m.	p.m.	a.m.	p.m.	p.m.	a.m.	p.m.
6	2	10	8	2	8	8	8
7	2	10	9	3	9	9	9
7	1	9	10	4	10	10	10
7	2	9					

The hours have been selected with a view to the deduction of a satisfactory value for the mean temperature for the day from the observations at the fixed hours, combined with the extreme readings. To obtain satisfactory means for other elements some modification of these hours may prove to be desirable.

In the British Isles 9 a.m. [3 p.m.] and 9 p.m., local time, have been adopted at Normal Climatological Stations. An observation in the early afternoon is necessary for the study of climate in relation to the humidity of the air, diurnal variation of wind and other elements, and the want of such observations at the British stations is a serious difficulty on that account.† The combination 7 a.m., 1 p.m. and 9 p.m. G.M.T. is also appropriate for Normal Climatological Stations in Britain, and is adopted for that purpose in the case of the Telegraphic Stations.

§ 2. THE REQUIREMENTS OF A NORMAL CLIMATOLOGICAL STATION.

I.—Instruments.

The instrumental equipment of a normal station consists of the following instruments :—

Mercury barometer reading to ·002 inch.
Dry bulb thermometer.
Wet ,, ,,
Maximum ,,
Minimum ,,
Raingauge.
‡Sunshine recorder.
‡Solar maximum thermometer.
‡Grass minimum ,,
‡Earth thermometers.

* *See* minute of September 12, 7th meeting of Congress, and "Codex" of Resolutions, p. 51.

† Since the commencement of 1909, space has been provided in the Monthly Weather Report for printing summaries of observations taken three times a day, and the summaries for a number of normal climatological stations are accordingly based on observations made at 9 a.m., 3 p.m., and 9 p.m.

‡ At some stations these are not included.

The barometer and thermometers must have "Kew certificates" from the National Physical Laboratory.

A lamp is required to read the instruments at night. At the Meteorological Office a hand electric lamp worked by a primary battery is used. A candle lantern is generally found to be convenient.

II.—Exposure of the Instruments.

Barometer.—The barometer should be kept indoors, but a good light and a uniform temperature are required, and it should also be protected against rough usage.

A position against a wall (specially plugged if necessary), bookcase, or other support in an unheated and little used room having a North aspect is very suitable. Should a sitting room be selected, the instrument should be so placed that it is not affected by direct heat from fires, hot water pipes, &c. A good light may generally be secured by selecting a position near a window, but the instrument should be shielded from the sun's rays at all hours of the day throughout the year. Provision must also be made for suitable artificial light, as observations are taken after sunset. Unless satisfactory natural illumination can be obtained it is advisable to use artificial light for all observations.

The height of the cistern of the barometer above mean sea level must be accurately known. The height of a conveniently situated "bench mark" should be ascertained from an ordnance survey map of large scale, and the difference in level between this and the barometer cistern determined by careful levelling (see p. 15). From the tables given on p. 126 it will be seen that a difference of level of 1 foot gives rise to a difference in the reading of the barometer of very nearly 0·001 inch, and hence the height of the barometer cistern above mean sea level should be known to the nearest foot.

Out-door Instruments.—The measures which are obtained of temperature and rainfall depend to some extent upon the exposure. In order that observations at different stations may be comparable, the exposures must be comparable. Strictly comparable exposure would require a site upon level ground with unrestricted exposure in all directions. This is not generally feasible, and for practical purposes it may be represented by a rectangular space of level short grass, about 30 ft. by 20 ft. surrounding the screen and raingauge, which should be not less than 10 ft. apart, the screen being placed to the North of the gauge. The distance of the instruments from any object (building or trees) should be twice the height of the object.

The plot should be upon generally level ground. A station on a steep slope, or in a hollow, is subject to exceptional meteorological conditions.

For a rural station the most unrestricted exposure should be aimed at, as the observations are intended to be comparable with other rural stations, and are of general meteorological interest. For urban stations local meteorological conditions are of importance, and an open space near the middle of the town is desirable.

A suitable site in an open space 300 ft. square would afford a quite satisfactory urban exposure.

Exposures on roofs are not appropriate for meteorological comparisons.

The above considerations are general. Each case in which they cannot be complied with requires special consideration.

Thermometers.—The dry and wet bulb thermometers, and the maximum and minimum thermometers, must be exposed in a screen of special construction.

Thermometer Screen.—The screen in general use is a Stevenson* screen, and is a box or cupboard with double-louvred sides (see Fig. 11, p. 26). Instructions for making it are given in Appendix V, p. 116.

The screen should stand on four legs above short grass and be painted white. The height of the bottom of the screen above the grass should be about 3 ft. 6 ins. The opening side of the screen should be to the North† or slightly East of North to avoid the effects of the sun shining on the instruments while observations are being taken.

The screen should be freely exposed to sun and wind; it should not be shaded by trees or buildings.

In tropical Countries where permanent short grass is not available the thermometers are hung in a wire cage within a hut which shades the ground below the instruments but allows a free circulation of air (see p. 26).

Raingauge.—The raingauge should have similar exposure, being fixed in a grass plot with its rim one foot above the grass level. The height above mean sea level of the ground on which the raingauge stands is conventionally taken as giving the height of the station (see p. 15).

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* Originally suggested by Mr. T. Stevenson, Engineer to the Board of Northern Lights. The specification adopted in this handbook was drawn up by a Committee of the Royal Meteorological Society.

† South in the Southern Hemisphere.

The plot of grass will also accommodate the solar maximum and grass minimum thermometers.

Other Observations.—In addition to accommodation for the instruments mentioned, provision must be made for ascertaining the direction of the wind by day and by night; this may be either by a wind-vane or by some fixed marks which enable the direction of smoke, &c., to be estimated with sufficient accuracy.

At some climatological stations, observations of earth temperature are taken with thermometers specially arranged for the purpose. The depths usually selected in this country for sanitary purposes are 1 ft. and 4 ft. Observations at 3 inches are sometimes made for agricultural purposes. The boring for the thermometer can be within the plot designed for the screen and raingauge.

Anemometer.—A normal climatological station is not usually provided with an anemometer. The velocity of wind near the surface is so much affected by obstructions of all kinds, that the satisfactory exposure of an anemometer is very difficult to obtain. It should be the subject of special consideration in each case.

Observations of wind force, which are sufficiently comparable with those of other stations, are obtained by estimation after the observer has had sufficient practice.

Sunshine Recorder.—This requires a perfectly free horizon between N.E. and S.E. on the East side, and between N.W. and S.W. on the West side, these being approximately the limits of the position of the rising and setting sun in our latitudes. Obstruction to the South should not be higher than from one-eighth to one-third of its distance from the instrument, according to the latitude of the station. Obstruction to the Northward between N.E. and N.W. is of no consequence. For the Southern Hemisphere the words South and North in the above description should be interchanged. For further particulars see p. 83.

The sunshine recorders in use at Meteorological Office stations are of the Campbell-Stokes pattern. (See p. 93 for specification of dimensions.)

III.—The Observer.

The services of a competent observer are required at 9 a.m. and 9 p.m. (local time) each day.* His occupation

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* For note regarding observations at 3 p.m. see p. 8.

should be such as to enable him to note the general character of the weather during the intervals between the observations at fixed hours. A competent deputy should be trained to take observations in the case of illness or absence of the regular observer.

§ 3. STANDARD TIME.

The time of observation should be specified on the form on which the observations are entered.

The hour for observing at normal climatological stations (stations of the second order) is referred to *local mean time.* At other stations the hours of observation are according to Greenwich mean time or the standard time of the country. It will be convenient at this stage to explain the meaning of these terms.

Apparent Solar Time.—Standard time for civil use is derived from the earth's rotation. The interval between two successive transits of the centre of the sun's disc over the meridian is a true solar day, and time based on the length of the true solar day is called "apparent time." A sundial or a sunshine recorder, when correctly set, indicates local apparent solar time.

Mean Time.—The length of the true solar day is not the same throughout the year. To avoid the obvious inconveniences which would arise from a want of uniformity in the length of the civil day, standard time is referred to an imaginary body called the "mean sun" which may be supposed to revolve uniformly round the earth, and complete each revolution in a time equal to the average length of the true solar day. Time referred to this "mean sun" is called *mean time*; the days measured on this convention are all of equal length.

Greenwich Mean Time.

The length of the mean solar day will be the same for all places on the Earth's surface, but the time of "mean noon," that is to say the time when the "mean sun" is due south, depends upon the line of geographical meridian of the place, and is different for different meridians. Thus in the numbering of the hours from noon or midnight every place has its own local mean time. Formerly it was usual for each locality to use its own mean time for civil reckoning, but now, by agreement, in order to avoid having to alter the time reckoning with every change of locality the local mean time of a selected place is used over the whole of a country. Thus Greenwich mean time (G.M.T.) is used for civil purposes all over the British Isles except in Canterbury and in Ireland. An observer can compare his watch accurately with Greenwich mean time by timing the 10h. a.m. time signal which is sent to all postal telegraph offices.

Recently the plan of using the mean time of a specified meridian as the standard time for the country has been extended by international agreement over nearly the whole world, the standard times of different localities being referred to the meridian of Greenwich or a meridian differing in time from that of Green-

wich by an exact number of hours or half hours. Thus the mean time of the meridian of Greenwich is the standard time for Western Europe (Belgium, France, Great Britain, Spain and Portugal), and is indicated by the letters W.E.T.

Mean time of the meridian 15° East of Greenwich or Middle European time is the standard time for Norway, Sweden, Denmark, Germany, Austria, Switzerland, Italy. It is an hour in advance of Greenwich time.

The following is a list of Standard Times* that have been adopted for railway and other purposes, referred to the Meridian of Greenwich :—

Europe—			
Mid-European	15°	E.	1 hour fast
East European	30°	E.	2 hours fast
South Africa ...	30°	E.	2 „
Asia—			
India	$82\frac{1}{2}$°	E.	$5\frac{1}{2}$ „
Burma ...	$97\frac{1}{2}$°	E.	$6\frac{1}{2}$ „
Hong Kong ...	125°	E.	8 „
Japan	135°	E.	9 „
Australia—			
West Australia	120°	E.	8 „
South „	$142\frac{1}{2}$°	E.	$9\frac{1}{2}$ „
Victoria ...	150°	E.	10 „
New S. Wales, Queensland, Tasmania	150°	E.	10 hours fast
New Zealand ...	$172\frac{1}{2}$°	E.	$11\frac{1}{2}$ „
America—			
Atlantic ...	60°	W.	4 hours slow
Eastern ...	75°	W.	5 „
Central ...	90°	W.	6 „
Mountains ...	105°	W.	7 „
Pacific ...	120°	W.	8 „

Local Mean Time.

The difference between local time for two places differing by a degree of longitude amounts to four minutes, *i.e.*, 24 hours for 360 degrees of longitude. Thus for a station in, let us say, longitude 5° W., which is very nearly the longitude of Truro in Cornwall, the difference between local and Greenwich time amounts to $4 \times 5 = 20$ minutes, and as Greenwich time is in advance of local time, 9 a.m. local mean time will correspond with 9h. 20m. a.m. G.M.T., and similarly for other hours.

Again, if we take a station situated to the east of the meridian of Greenwich, say Yarmouth in Norfolk, of which the longitude is 1° 43′ E., the difference amounts to $1\frac{43}{60}^\circ \times 4 = 6\frac{52}{60}$, or practically 7 minutes, and as Greenwich time now lags behind local time, 9 a.m. local time will correspond with 8h. 53m. a.m. G.M.T., and similarly for other hours.

Irish Standard Time.—In Ireland the mean time of Dublin is the standard time of the country, except for telegraphic business; it is 25 minutes *slow* compared with Greenwich mean time, the longitude of Dublin being $6\frac{1}{4}$° W.

Local mean time for other stations in Ireland can be derived from Dublin mean time if the difference in longitude between Dublin and the station is known. Thus at Valencia, of which the longitude is $10\frac{1}{4}$° W., the difference in time amounts to $(10\frac{1}{4} - 6\frac{1}{4}) \times 4 = 16$ minutes, and 9 a.m. local mean time corresponds with 9h. 16m. a.m. by standard (Dublin) time.

* *See* the Nautical Almanack for 1909.

Local Apparent Solar Time.

As one of the methods for the determination of the meridian depends on the fact that the sun is exactly south at local apparent noon, and as sunshine recorders must be set by apparent and not by mean time, it will be convenient while discussing the question of time to indicate how apparent solar time can be computed from mean local time.

The difference between the two reckonings is known as the "equation of time"; its amount for every third day of the year is given in the following table :—

TABLE giving for every Third Day in Leap Year the Equation of Time to the nearest half minute, to be ADDED TO or SUBTRACTED FROM Local Mean Time according as the sign is + or −, in order to get Local Apparent Time.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	− 3½	−14	−12½	−4	+3	+2½	−3½	−6	+ ½	+10½	+16½	+10½
4	− 5	−14	−12	−3	+3½	+2	−4	−6	+ 1½	+11½	+16½	+ 9½
7	− 6½	−14½	−11	−2	+3½	+1½	−4½	−5½	+ 2½	+12½	+16	+ 8
10	− 7½	−14½	−10½	−1	+4	+1	−5	−5	+ 3½	+13	+16	+ 7
13	− 9	−14½	− 9½	− ½	+4	0	−5½	−4½	+ 4½	+14	+15½	+ 5½
16	−10	−14½	− 8½	+ ½	+4	− ½	−6	−4	+ 5½	+14½	+15	+ 4
19	−11	−14	− 8	+1	+3½	−1	−6	−3½	+ 6½	+15	+14½	+ 2½
22	−11½	−14	− 7	+1½	+3½	−2	−6	−2½	+ 7½	+15½	+13½	+ 1
25 .. .	−12½	−13½	− 6	+2	+3½	−2½	−6	−2	+ 8½	+16	+12½	− ½
28	−13	−13	− 5	+2½	+3	−3	−6	−1	+ 9½	+16	+11½	− 2
31	−13½	..	− 4	+3	+2½	−3½	−6	0	+10½	+16½	+10½	− 3½

The sign + indicates that the amount shown must be ADDED to the mean local time in order to compute apparent solar time. Thus, to take an example, suppose it be desired to compute the apparent solar time corresponding to noon G.M.T. at a station near Truro, longitude 5° W., on August 6th. We have seen above that the mean local time is 20 minutes slow of G.M.T., and hence noon G.M.T. corresponds to 11.40 a.m. local mean time. From the table given above we find that the correction which has to be applied to the *local mean time* on August 6th is—5½ minutes, hence the apparent solar time corresponding to noon G.M.T. is 11 hours (40 − 5½) minutes, *i.e.*, 11 hours 34½ minutes a.m. Thus Greenwich mean time on this day is 25½ minutes ahead of local apparent time, and at noon local apparent time, a clock which shows Greenwich mean time would read 25½ minutes past noon. At this moment the sun would be on the meridian of the place, *i.e.*, it would be due South.

On the other hand, if we had selected a day for which the equation of time is positive, say October 28th, for which it is + 16 minutes, this amount would have to be added to the local mean time, so that noon G.M.T. would correspond with 11 hours (40 + 16) minutes, *i.e.*, 11.56 a.m. The difference on this day between local apparent time and G.M.T. is thus reduced to 4 minutes. Noon by local apparent time corresponds to 12h. 4m. p.m. G.M.T.

§ 4. SITE AND ORIENTATION.

The particulars required for the specification of the site of a meteorological station are its latitude and longitude, and the height above mean sea level of its raingauge and

barometer. The orientation of the site of the station with reference to surrounding objects is necessary for the specification of winds and cloud motion and other purposes.

Latitude and longitude can be taken from a 6-inch ordnance map and should be given to the nearest minute. It may be noted in this connexion that a degree of latitude corresponds nearly with sixty-nine statute miles, a degree of longitude in latitude 60° with half that distance.

Levels can be taken from an ordnance map which gives the exact height of a number of "Bench Marks." These are actually cut in walls or mile stones or some other permanent land mark thus ⩚, generally speaking at the roadside and are indicated in the ordnance map by the letters B.M. with the height in feet. A spirit level, a straight edge and a graduated staff enable the observer to "run a line of levels" from the nearest mark to his station.

The height of the "observatory" is to be entered as the height of the ground on which the rain gauge stands.

The orientation (points of the compass) may be determined in the following manner :—

(1) The most direct method is to determine, from an ordnance survey map, the bearings with regard to the station of a number of conspicuous objects in the neighbourhood, such as church steeples or prominent points in the landscape features. The map on the scale of six inches to the mile, will be found most suitable. The one-inch map may serve if the position of the station can be exactly identified upon it. The observer will then have little difficulty in identifying the directions of the principal points, North, East, South and West, and the intermediate points.

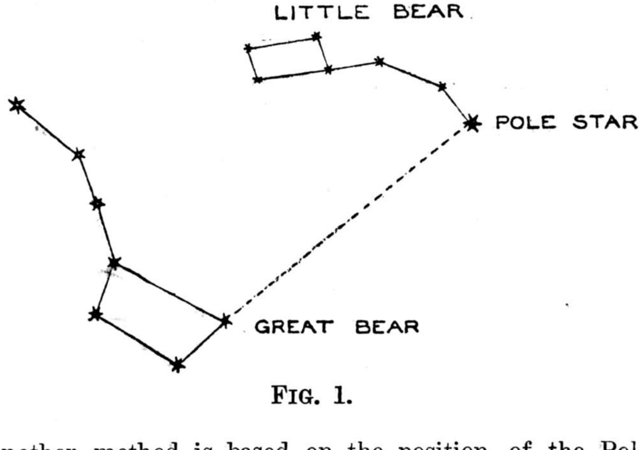

FIG. 1.

(2) Another method is based on the position of the Pole star, which is easily identified on any clear night. It is the last star in the "tail" of the constellation, known as the "Little Bear" (*ursa minor*). If the straight line which joins the two bright stars in the

quadrilateral of the "Great Bear," furthest from the "tail" be produced, it passes nearly through the Pole star (*see* Fig. 1). This star marks the North point with sufficient accuracy. The plane of the meridian, or in other words, the North-South plane, passes through the Pole star, the zenith and the observer.

(3) The method of determining the direction of the plane of the meridian from the position of the sun at noon, local apparent time, has been referred to above (p. 14). In this connexion the shadow thrown by a stick, carefully adjusted to be vertical, can be usefully employed to identify the meridian position of the sun.

(4) The orientation of a station can be and often is accurately determined by the magnetic compass; but the matter requires care and attention to the following points. A compass needle does not point to true North, the amount of the divergence differs slightly for different places, and it is also not absolutely constant for one and the same place. In the British Isles at the present time the magnetic needle points to the West of true North, and the amount of divergence for any place can be read off on the map (Fig. 2), on which the lines of equal declination or variation from true North are shown.* All directions determined by compass bearing must be corrected by this amount before being adopted in meteorological work.

The amount of the declination or variation from true North is at present decreasing by about 6 minutes per annum in the neighbourhood of the British Isles.

A second and more dangerous source of error in the determination of direction by means of a magnetic compass is connected with the disturbing effects which may be introduced by the presence of iron or steel bodies, or of powerful electric currents. When using a compass the observer must satisfy himself that all such possible sources of disturbance are absent. Even the presence of such small objects as iron nails in the support on which the compass is placed, or of knives or keys in the observer's pockets may cause serious errors of unknown magnitude.

The Specification of Direction.

Direction is usually specified in accordance with the scheme shown on the annexed diagram (Fig. 3, p. 17).

Sufficient precision is secured by the division of the circle into 16 equal sectors. It is generally not possible to determine the directions of wind or cloud with greater accuracy without special apparatus.

When great accuracy is attainable, or a large number of observations have to to be dealt with, direction is usually specified by stating the number of degrees to the eastward or westward of North or South. A more systematic method is to quote the number of degrees divergence from geographical North, the measurement being carried round the complete circle in a clock-wise direction. The principal

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* **For stations in other regions the amount can be read off from the frontispiece map which shows the isogonic lines for the whole world.**

To face p. 16.

MEAN LINES OF EQUAL WESTERLY MAGNETIC VARIATION, 1907.

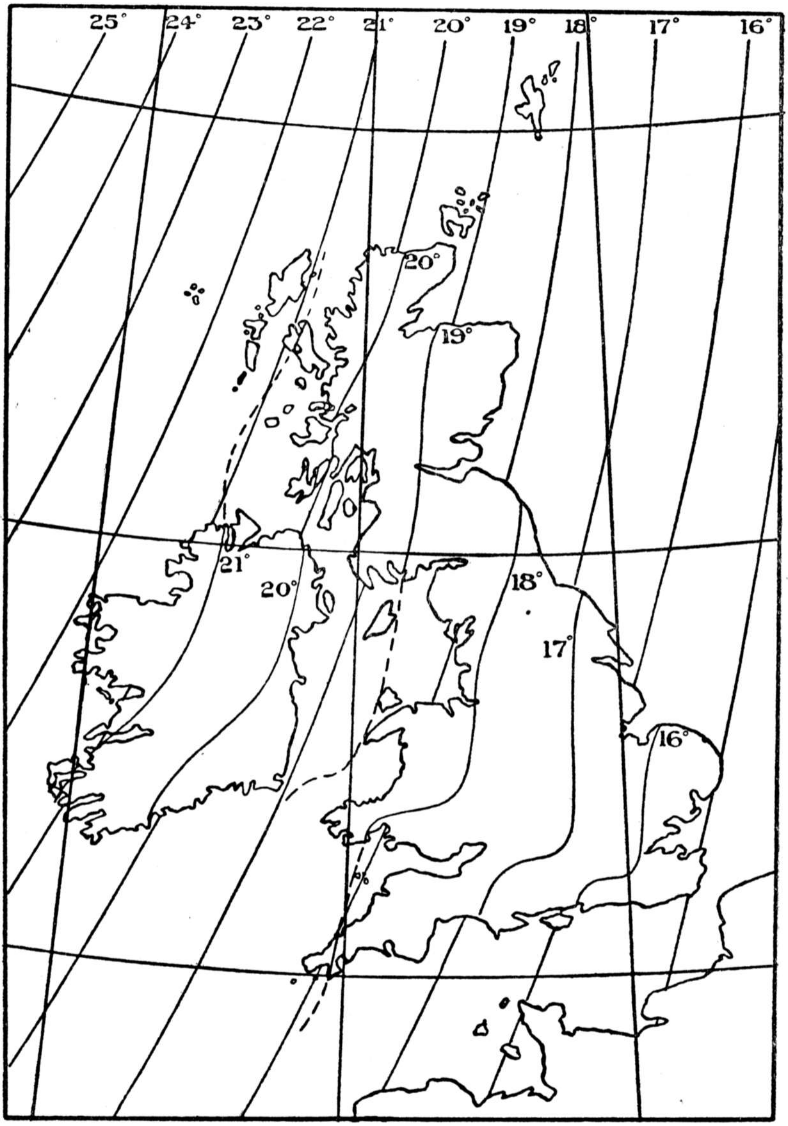

FIG. 2.

The lines, as drawn over the sea, are taken from the Admiralty charts; those over the land are taken from a special chart prepared from shore observations and communicated by the Hydrographer of the Navy.

The magnetic declinations at British Observatories for the epoch 1912 are approximately Eskdalemuir, 18° 5′. Stonyhurst, 17° 5′. Valencia, 20° 30′. Greenwich, 15° 25′. Kew, 15° 45′. Falmouth, 17° 25′.

points are then designated by the numbers E. = 90°, S. = 180°, W. = 270°, N. = 360°.

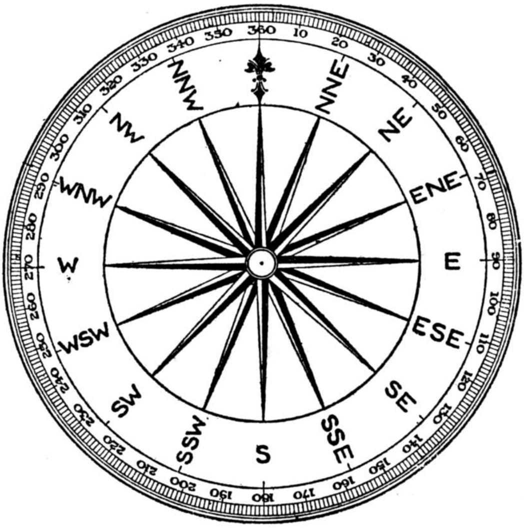

FIG. 3.

§ 5. THE POCKET REGISTER.

All the original observations should be written down at the time of observation in a properly ruled note book which should be preserved for reference in case any question should subsequently arise about them. The practice of jotting down the readings on odd scraps of paper with the intention of copying them subsequently is to be deprecated as liable to lead to errors.

The entries in the book should *under no circumstances* be altered or erased; errors should be noted in the margin. Doubtful entries should be marked with a query. Should observations be missed altogether, the words "no observations" should be written in the corresponding columns.

Punctuality is of the greatest importance. Should the observations be taken more than 10 minutes earlier or later than the fixed hour, a note to that effect should be made in the margin.

In addition to the observations at fixed hours, unusual phenomena such as fogs, thunder, or hailstorms, &c., and the hour of their occurrence and their duration, should be noted in the "remarks" column at the time of their occurrence or as soon thereafter as practicable.

The pocket register should also contain a record of all changes in the equipment of the station or in the exposure of the instruments, and of the times when the latter are cleaned or adjusted. The most trivial details of actual fact in these matters frequently prove useful at a later date.

§ 6. NOTES ON THE USE OF INSTRUMENTS AT NORMAL CLIMATOLOGICAL STATIONS.

The Mercury Barometer.

The barometer in general use in the British Isles is the Kew Pattern Station Barometer. We shall therefore first give instructions for that instrument and subsequently indicate how to manage the Fortin barometer, which is another type of instrument suitable for stations, but more difficult to handle.

General caution.

Attention may at this stage be called to the necessity for exercising great care in handling a barometer. Should it be required to move the instrument, first incline it very gently, so as to allow the mercury to flow very slowly to the top of the tube. With the tube thus filled the barometer may be transported with safety in a horizontal or in an inverted position (cistern end uppermost), provided it is not subjected to sudden concussions. If carried while in its usual position, *i.e.*, with a free mercury surface in the tube, the heavy mercury striking against the glass will probably cause breakage. In the case of a Fortin Barometer the plunger which will be found at the base of the cistern must be screwed up until the mercury completely fills the tube, before the instrument is moved. (*See* p. 24).

To mount the Instrument.

Having selected a position in accordance with the instructions given on p. 9, screw the socket, which will be found in the case, to the support. Lift the barometer carefully from its case and slip the hinged part of the suspension arm into the socket. Take care that the screws which secure the instrument in its gimbals are screwed home, otherwise it may slip through its supports.

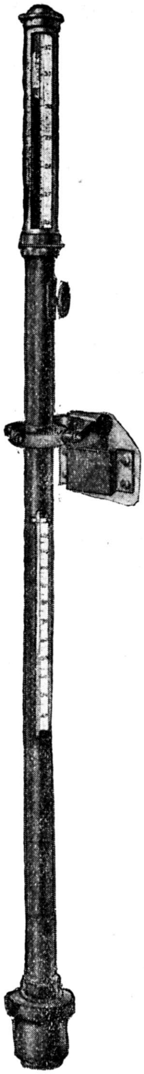

Fig. 4. Kew Pattern Barometer.

When in position the top of the barometer should be at such a height that the observer can read the scale comfortably while standing upright.

The method of suspension in gimbals secures that the scale is vertical *when the instrument is hanging quite freely.* Any deviation from the vertical causes the reading to be too great. To facilitate setting, a white screen or a sheet of white paper should be fixed to the wall behind the scale.

No observation should be taken until at least two hours have elapsed after fixing, in order that the mercury may have time to acquire the temperature of the air. The tube of some station barometers is much constricted to avoid "pumping"; a considerable time is then required for the mercury to reach its true level after being first set up. The behaviour of the barometer in this respect should be tested by tilting the tube until it is full to the top and then noting the time required for it to recover approximately its old position.

Before a reading is taken the barometer should be tapped with the fingers, and the tapping continued until it ceases to produce an effect on the shape of the mercury surface.

To take an Observation.

(1.) **Attached Thermometer.**—Observe and note in the appropriate column of the register the temperature of the thermometer attached to the barometer

This should be done first as changes in temperature due to the presence of the observer are likely to affect the thermometer more quickly than the mercury in the tube.

NOTE.—The scale of the Kew pattern barometer is graduated so as to allow for variations in the level of the mercury in the cistern and no adjustment is therefore needed for such changes.

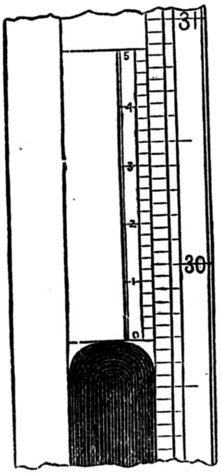

FIG. 5.

(2.) **Setting the Vernier Scale.**—Turn the milled head at the top of the instrument until the lower edge of the small moveable scale, called the vernier, and also the lower edge of the sliding piece at the back of the instrument which moves with the vernier appear in the same straight line and touch the uppermost part of the domed surface of the mercury.

Care must be taken to touch the instrument as lightly as possible, and on no account to read it when displaced from the vertical position.

When the adjustment has been made, no part of the mercury should be hidden by the scale, and yet it should be impossible to see the white paper (*see* p. 19) between the edge of scale and the *highest* point of the mercury surface. As the latter is curved the paper will of course be visible at the sides (*see* Fig. 5).

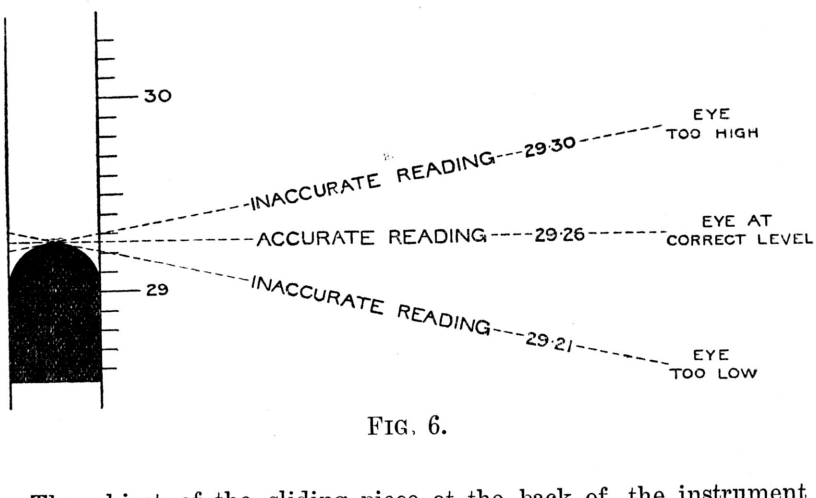

FIG. 6.

The object of the sliding piece at the back of the instrument is to ensure that the observer's eye is at the same level as the top of the mercury column; if this is not the case, serious errors are made, as will be seen from the accompanying diagram (Fig. 6). Errors of this nature which are liable to be made whenever the index and the scale on which it is read are not in the same plane are known as **errors of parallax.**

(3.) **Reading the Scale.**—Take the reading and enter the observation as read in the appropriate column of the register. The mode of reading off may be learned from a study of the following diagrams, in

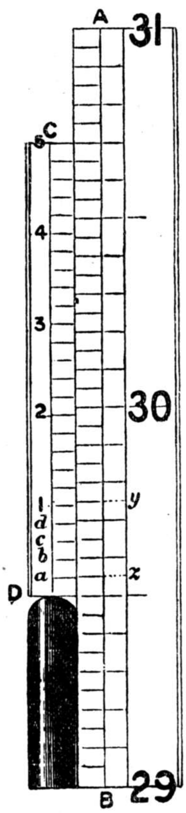

FIG. 7.

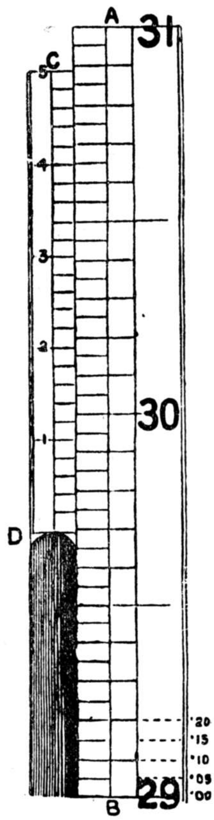

FIG. 8.

which AB represents part of the scale, and CD the vernier, the *lower* edge D denoting the position of the top of the mercurial column. The scale is readily understood; B is 29·000 inches; the first line above B is 29·050; the second line 29·100, and so on. The first thing is to note the scale line just below D, and the next is to find out the line of the vernier which is in one and the same direction with a line on the scale. In Fig. 7, the lower edge of the vernier D is supposed to be in exact coincidence with scale line 29·5; the barometer therefore reads 29·500 inches. Studying it attentively in this position it will be perceived that the vernier line *a* is ·002 inch below the next line of the scale. If, therefore, the vernier be moved so as to place *a* in line with *z*, the edge D would read 29·502. In like manner it is seen that *b* is ·004 inch away from the line next above it *on the scale*; *c*, ·006 inch apart from that next above it; *d*, ·008 inch from that next above it; and 1, on the vernier, is ·010 below *y*. Hence, if 1 be moved into line with *y*, D would read 29·510. Thus the numbers 1, 2, 3, 4, 5, on the vernier, indicate hundredths, and the intermediate lines the even thousandths

of an inch. Referring now to Fig. 8, the scale line next below D is 29·650. Looking carefully up the vernier, if the third line above the figure 3 had coincided with a line on the scale, the reading would have been estimated as follows :—The number 3 indicates ·030, and the third subdivision ·006 ; thus we get :—

Reading on scale	29·650
Reading on vernier	·030 ·006
Actual reading	29·686 inches.

In Fig. 8, however, two pairs of lines appear to be almost coincident, and in this case the intermediate thousandth of an inch should be set down as the reading. Thus the reading appears to be 29·684 or 29·686, and the mean 29·685 should be adopted.

Special caution.—The attention of the observer is drawn to the fact that errors of ·050, or less frequently of ·010, inch, *i.e.*, errors in counting the number of divisions on the fixed scale, are very liable to occur unless great care is taken. *If the vernier has not been shifted between two observations, it is advisable to check the previous reading before proceeding to a fresh setting.*

The Reduction of Barometer Readings.

A number of corrections must be applied to the reading obtained as described above.

(1.) **Index error.**—Should there be any error in the scale of the barometer the appropriate correction, as given in the Kew certificate, should be added or subtracted.

(2.) **Temperature.**—Changes of temperature affect both the density of mercury and the length of the scale of the barometer, and hence the reading of the instrument is not independent of its temperature. In order to obtain comparable results it has been agreed to reduce all barometric readings to what the instrument would have read under the same conditions of pressure if it had been at a standard temperature. The freezing point of water, 32° Fahrenheit, has been universally adopted as the standard temperature.

The amount of the correction for each degree of temperature of the **attached thermometer** is given in Table I., pp. 124, 125. At temperatures below 29° the amounts shown in the table are to be added, at temperatures above this limit they are to be subtracted.

(3.) **Gravity.**—The force of gravity varies slightly with the latitude, and hence barometric readings require to be reduced to a standard latitude. 45° is the latitude adopted. The amount of the correction for each degree of latitude is given in Table III., p. 130 ; it is to be added or subtracted according as the sign in the table is + or —. It should always be quoted at the head of tables of barometer readings.

The correction should be applied in all cases to the readings of barometers before publication, with those for index error and temperature. (See columns 7 to 9 on the specimen form on p. 102.)

Reduction to Mean Sea Level.

A further reduction must be applied to barometric readings intended for use in synoptic charts. All such readings must be reduced to a standard altitude, and for the latter the mean sea level is universally adopted. To effect the reduction an amount must be added to the observed reading which is equal to the length of the column of mercury required to balance a column of air equal in height to the height of the cistern of the barometer above mean sea level. The size of this correction will depend to some extent on the pressure, temperature, and humidity prevailing at the time. Tables showing the amount to be added under different meteorological conditions have been drawn up by various authors: those prepared under the direction of the International Meteorological Committee in conformity with resolutions adopted by the Congress of meteorologists which met at Rome in 1879 are recommended for adoption. In these tables full instructions are given for taking account of all the elements mentioned above.

Table II. (*see* pp. 120–122, 126–129) has been calculated from the international tables; it gives the amounts which must be added to barometer readings of 27 and 30 inches respectively in order to reduce them to mean sea level, for every 10 degrees of temperature and for increments of altitude of 10 feet up to 1,000 feet. Interpolated values must be used for intermediate altitudes, temperatures, or pressures.

For the convenience of its observers the Meteorological Office will supply, on application, manuscript tables for effecting the above corrections and reductions in which the corrections for index error and gravity are combined with the reduction to sea level. These tables refer only to the heights and instruments for which they are made out and minimize interpolation.

We proceed to give an illustration of the method of applying the corrections.

Altitude of cistern of barometer above M.S.L.	722 feet.
Latitude of station	55° N.
Dry bulb thermometer in screen	38°
Attached thermometer	62°

Barometer reading uncorrected	29·936 inches.
Index error (*see* Kew Certificate)	+·001
Correction for reduction from 62° to the freezing point (from Table 1)	—·091
Correction for gravity	+·027
Reading at 32° F. at level of station and standard gravity	29·873
Reduction to mean sea level (Temp. 38°, Table II.)	+·823
Corrected reading at mean sea level	30·696 inches.

Sufficient accuracy will be attained if the reading is given correct to the nearest 0·01 inch, and the reading in the above example may therefore be quoted as 30·70 inches. To secure this degree of accuracy it is necessary to retain three places of decimals until the final step is reached.

The Fortin Barometer.

This instrument differs from the Kew pattern barometer—

(1.) In the method of suspension.

(2.) In the fact that it is necessary to adjust the surface of the mercury in the cistern to a fixed level before taking an observation. The scale is thus graduated to true inches.

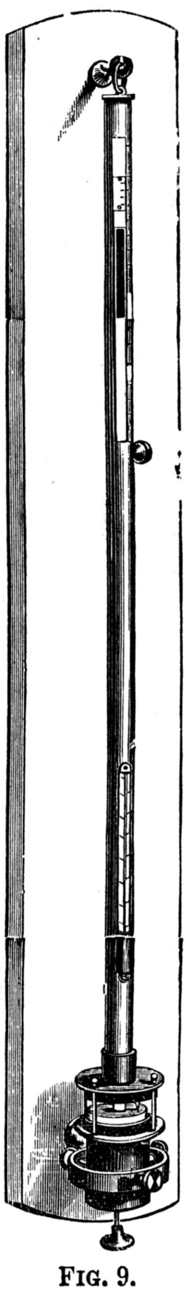

FIG. 9.

Instructions for Mounting and Handling.—To mount the barometer, fix the board which is supplied with it in the selectedposition, taking care that it is *vertical.* Then lift the instrument out of its case and suspend it from the hook fixed to the upper part of the board. The lower end should be passed through the ring attached to the lower portion of the board.

The barometer is so constructed that the scale is vertical *when the instrument is hanging freely.* It should be permanently fixed in the vertical position by adjusting the length of the three screws which will be found on the ring through which the lower end passes until their ends just touch but do not displace the barometer. Any displacement from the vertical will cause the reading to be too great. The correctness of the adjustment should be tested from time to time by loosening the screws until the instrument hangs quite freely and then screwing them carefully up again. The screws must be kept clean and if necessary they may be slightly oiled ; if they work stiffly it is impossible to make the adjustment satisfactorily.

If a Fortin barometer is to be dismounted, the plunger which will be found at the base of the cistern should first be screwed up until the mercury entirely fills the barometer tube. When this has been done the instrument may be transported in a similar manner to a Kew pattern barometer.

The scale of the Fortin barometer is graduated into true inches, and it is so fixed that its zero coincides with a fixed index, called the **fiducial point,** in the cistern. Before taking an observation the surface of the mercury in the cistern must be made flush with the fiducial point, which usually takes the form of an ivory point or knife-edge. The adjustment is made by screwing the plunger at the base of the cistern until the tip of the index is exactly coincident with its image in the mercury. A good light is as essential in making this adjustment as in setting the vernier, and artificial light should always be

used whenever good daylight fails. In the Newman type of barometer, in use at many observatories, the scale is rigidly attached to the fiducial point which forms the zero of the scale. The adjustment is made by moving the scale up or down by means of a rack and pinion, and not by altering the position of the mercury surface.

The adjustment should be made immediately after reading the attached thermometer. To prevent fouling of the mercury by prolonged contact with the index, the plunger should be unscrewed after each observation so as to leave the mercury surface well below the point of the ivory index.

Defects of Barometers.

The chief defect to which mercury barometers are subject is due to the accumulation of air in the space above the mercury. The presence of air may be detected by slightly inclining the tube so as to allow the mercury to flow slowly to the top of it. If a sharp metallic "click" is heard as the mercury strikes against the glass it may be assumed that no air is present. To expel air when present the instrument should be carefully inverted (the precautions described above being taken, *see* pp. 18, 24) and be gently tapped while in this position. In the case of Fortin barometers this treatment generally suffices to remove the air, but in the case of Kew pattern barometers in which the tube is very much constricted it may be necessary to send them to an instrument maker for repair. They should be sent subsequently to the National Physical Laboratory, for a redetermination of their index errors.

FIG. 10.

To prevent air and moisture working their way into the "vacuum" of a Kew pattern barometer, a small funnel or "pipette" is inserted between the cistern and the top of the mercury column (*see* Fig. 10). With this arrangement the air gets entrapped at the shoulder A and does not affect the reading of the barometer.

TESTING OF A BAROMETER BY MEANS OF DAILY WEATHER CHARTS.

The accuracy of a barometer may be tested roughly by comparing its indications with the pressure values deduced from the isobaric charts published in the Daily Weather Report. For this purpose readings should be taken at 7 a.m., G.M.T., and reduced to mean sea level and latitude 45° by the methods given above (pp. 22, 23). The height of the barometer cistern above M.S.L. must be known. On the charts the isobars or lines of equal pressure are given for M.S.L. for the epoch 7 a.m. on the day of the chart. The position of the station on the map being known, the approximate pressure at it can be read off from the isobars. Suppose for instance that the station lies between the isobars marked respectively 29·8 and 29·9, and suppose further that the perpendicular distance of the station from the isobar for 29·8 is three-tenths of the whole distance between the isobars; the reading at the station may then be taken as 29·83 inches. As a general rule the pressure can be determined in this manner with an error of not more than ·03 inch, but as the method involves some uncertainty a series of comparisons should be made.

The Thermometers.

The Screen.—The dry bulb, the wet bulb, and the maximum and minimum thermometers require to be exposed in a screen of approved pattern. The screen in general use in this country* is the Stevenson screen ; it is a box or cupboard with double louvred sides. Directions for constructing it will be found in appendix V., p. 116.

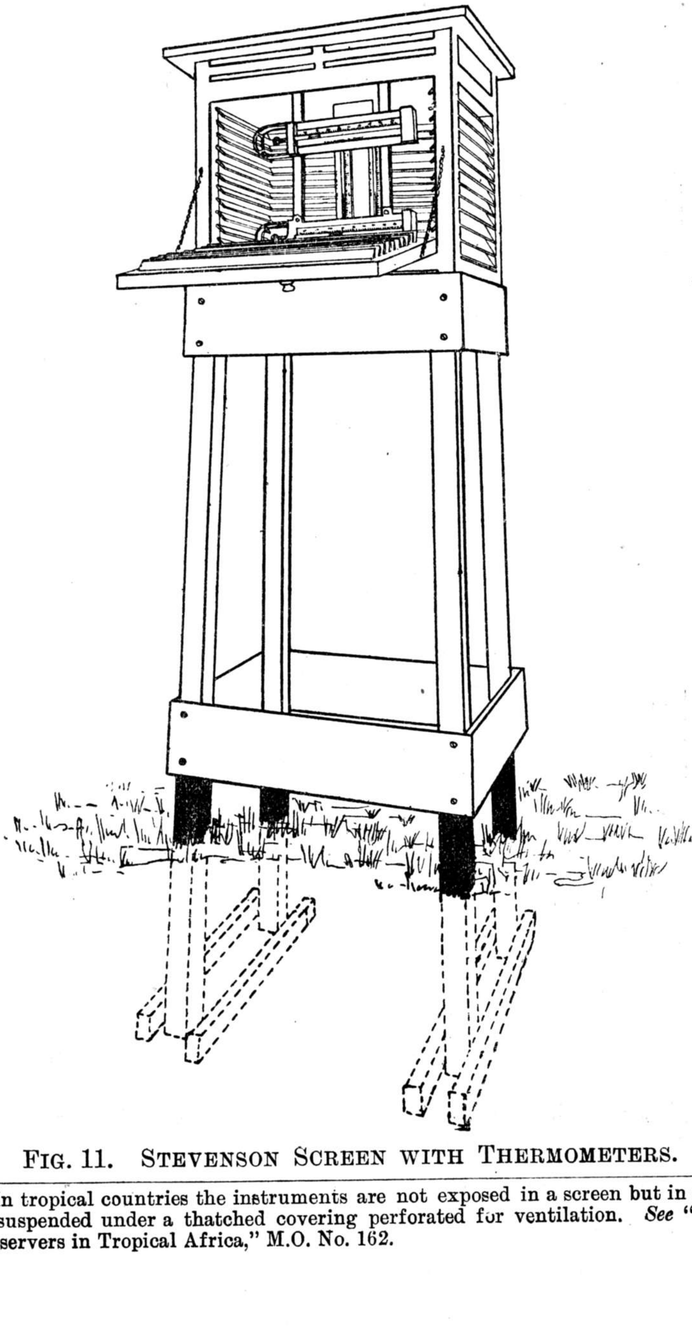

FIG. 11. STEVENSON SCREEN WITH THERMOMETERS.

* In tropical countries the instruments are not exposed in a screen but in a wire cage suspended under a thatched covering perforated for ventilation. *See* "Hints to Observers in Tropical Africa," M.O. No. 162.

Exposure.—The conditions which the exposure of the screen should satisfy have been described on p. 9. It should stand on four legs so that its base is about 3 feet 6 inches above the level of the ground. The legs must be sufficiently rigid and be buried sufficiently deeply in the ground to prevent shaking during gales. (*See* also (3) below). To prevent rot the portions below ground should be creosoted or otherwise treated. There should be no boarding or slab under the base of the screen. The opening of the screen should face towards the north (south in Southern Hemisphere) or, preferably, somewhat east of north so that the sun may not shine on the instruments while observations are being taken.

Arrangement of the Thermometers in the Screen.

In arranging the thermometers in the screen the following points must be borne in mind :—

(1.) There should be a space of at least three inches between the bulbs of the thermometers and the top, bottom or sides of the screen.

(2.) The thermometers should be so arranged that all parts of their scales can be read without the necessity for moving any one of them.

(3.) The maximum and minimum thermometers should be clamped down so that strong winds cannot shake them, as jolting often leads to displacement of the indexes. The instruments require to be moved once a day for setting, and therefore cannot be screwed in position.

A suitable arrangement is shown in Fig. 11.

The Maximum Thermometer.

The maximum thermometer is designed to record the highest temperature experienced during a given period. Two forms of instrument are in common use. Both are mercurial thermometers. In the Negretti and Zambra pattern adopted by the Meteorological Office the tube is greatly constricted just above the bulb. It is hung nearly horizontally with the bulb end slightly lower than the other. (*See also* p. 28.) As the temperature rises the mercury expands and is forced past the constriction, but, when a subsequent fall of temperature causes a contraction of the mercury, the thread breaks at the constriction so that its upper end remains in position to register the highest temperature reached.

Phillips' pattern is also hung horizontally. In it there is no constriction in the tube, but a small air bubble is placed in the mercury thread near the bulb. As the temperature falls the part of the mercury beyond the bubble is not drawn back towards the bulb and thus the end of the mercury column marks the highest temperature reached.

The Minimum Thermometer.

The minimum thermometer records the lowest reading experienced in a given interval. The most common type of instrument is a spirit thermometer having a small index in the stem. It is hung like the maximum thermometer. As the temperature falls the index is carried towards the bulb by the spirit, but if the latter subsequently expands in consequence of a rise of temperature, it flows past the index which is left in position to indicate the lowest temperature reached.

General Hints on the Management of Thermometers.

The thermometers should be kept clean and the bulbs bright. If water has condensed on any of the thermometers it should be wiped off, and several minutes should be allowed to elapse before the readings are taken.

Blacking the Scale.—Should the divisions of the scale become indistinct they may be renovated by rubbing in lamp-black or black-lead scraped from a soft pencil and moistened with oil, which catches in the divisions but can be rubbed off the intervening spaces by passing the finger or a cloth lightly over the scale.

Bubbles in Stem of Spirit Thermometers.—Spirit thermometers should be regularly examined for the presence of bubbles in the stem or bulb, or of drops of liquid in the upper part of the stem or in the small bulb at its end. To remedy this defect when present, hold the thermometer with the bulb downward and the tube vertical and jolt the bulb end of the frame, or if there be no frame, the hand holding the thermometer, gently against a soft pad keeping the instrument vertical all the time. One's knee, or a thickly folded table cloth, forms a very suitable pad to prevent the jar being too severe. By repeating this treatment several times detached globules of spirit may be made gradually to approach the main bulk of spirit, and ultimately the whole thread becomes continuous. After all visible drops or bubbles have been removed in this way the thermometer should be left for a short time in a vertical position, bulb downwards, to allow any liquid which may have collected on the walls of the tube to drain down to the main column. With the same object it is advisable to stand spirit thermometers in this position for an hour or two once every fortnight.

Occasionally the thread of a mercury thermometer gets broken; the defect may generally be remedied by jolting as described above.

Defects of Maximum Thermometers.—Maximum thermometers are subject to two defects—

(1.) The mercury may recede from its maximum position when the temperature falls below the maximum to a greater or a less extent. The observer should accordingly test his instrument occasionally by gently heating it and noting whether the mercury column retains its position in the tube.

(2.) The mercury may slip forward when the instrument is brought into a horizontal position after setting.

Both these defects may in most cases be remedied by altering the inclination at which the instrument hangs.

The management of the wet bulb thermometer will be discussed under the heading Hygrometers. (*See* p. 33.)

Reading the Thermometers.

Sighting. Errors of parallax.—As the mercury thread and the scale of the thermometer are not in the same plane, errors of **parallax** (*see* p. 20) will be made unless the observer is careful that the straight line joining his eye to the top of the mercury or spirit column is at right angles to the stem of the instrument. This condition will be fulfilled if he places his eye at the same level as the end of the mercury column if the thermometer be vertical, or directly in front of it if it be horizontal.

Degree of accuracy required.—To obtain satisfactory values for the vapour pressure and relative humidity from readings of dry and wet bulb thermometers, the **difference** between the readings of these instruments must be known with accuracy, and hence the observer should estimate fractions of a degree to the nearest **tenth.** To do this he should imagine the degree divided into two equal parts as at B (Fig. 12), and each of these halves again subdivided into quarter degrees as at C and D. If the end of the mercury column falls within the first quarter, the correct fraction will be ·1 or ·2 and the observer must use his discretion which value he enters in the register. Similarly the values ·3 and ·4 fall within the second quarter; ·5 represents the half degree; ·6, ·7, and ·8, ·9 fall within the third and fourth quarters respectively. Thus in Fig. 12 the points V, W, X, Y, and Z read 0·3, 1·1, 2·6, 3·4, and 4·8 respectively.

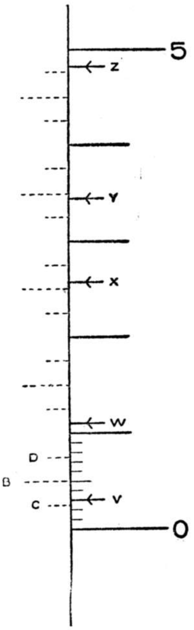

FIG. 12.

Maximum and minimum thermometers need only be read to *whole* degrees. If the readings are estimated to tenths the entries in the Monthly return should be rounded off to the nearest whole degree, after correction for the errors of the thermometers.

When a thermometer is read to a whole degree it should be the nearest degree, *e.g.*, if the extremity of the mercury column or the end of the index be between 49° and 50°, but nearer 50° than 49°, 50° should be entered.

Where the corrected reading comes half way between two degrees *i.e.* at 0·5 the higher should be entered in the return. For example all corrected readings from 49·5 to 50·4 would be entered as 50° while 50·5 would be entered as 51°.

Rapidity.—The thermometers should be read as rapidly as is consistent with accuracy in order to avoid changes of temperature due to the presence of the observer. When observing by artificial light care must be taken not to heat the thermometers with the lamp.

Hours of Observation and Setting.—At *normal climatological stations* the instruments will be read at 9 a.m., 3 p.m., if possible, and 9 p.m. (9h., 15h., and 21h.) local time. It was agreed at the Congress of Vienna that the operation of setting the maximum and minimum thermometers should be performed only once in 24 hours, and that the latest hour of observation should be selected for the purpose. In this country 9 p.m. will accordingly be the hour for setting.

At *auxiliary climatological stations*, where readings are taken only once a day (9 a.m.), the temperature registered by the maximum thermometer will as a rule have occurred on the previous day, and the reading should **in all cases** be entered to the **previous day.** The minimum temperature should always be entered to the day of reading. Should it be necessary to set the instruments at an hour other than

9 p.m. at a normal climatological station, the fact should be entered on each sheet of the register.

The values of monthly means of maximum and minimum temperature depend to some extent on the hour selected for setting the thermometers. If an hour in the afternoon be selected, it will sometimes happen that the maximum temperature for the 24 hours will be the dry bulb reading at the time of setting, and therefore we must expect the monthly mean to become higher the nearer the hour selected for setting approaches the normal time of maximum temperature. At many stations a supplementary observation is taken at 6 p.m. for communication to newspapers. Monthly means based on readings taken at this hour are not suitable for climatological comparisons. For such comparisons the thermometers must be set at 9 a.m. or 9 p.m. (or at 7 a.m., if comparison with data contributed by the telegraphic reporting stations of the Meteorological Office is desired).

Reading and Setting.—When taking a complete observation proceed as follows :—

(1.) Enter the readings of the dry and wet bulb and the maximum and minimum thermometers in the appropriate columns of the pocket register. In the cases of the first three instruments the position of the end of the mercury column is observed ; in that of the minimum thermometer the position of the end of the index *furthest from the bulb* must be noted.

(2.) Check these entries—

(*a*) By comparing them again with the instrumental readings, special attention being directed to making sure that no errors of 5° or 10° have been made.

(*b*) By ascertaining that the reading of the maximum and minimum thermometers are respectively as high or higher, or as low or lower than the dry bulb readings taken at or since the previous setting ; the maximum reading should be at least as high as, and the minimum at least as low as those readings.

(3.) Set the maximum and minimum thermometers. The former may be set by swinging it briskly through the air, the bulb being held away from the observer, or by jolting it while in a vertical position. If the thermometer be of Phillip's pattern (*see* p. 27), it must not be jolted violently as there is danger of shaking the air bubble out of the mercury column, when the thermometer will act as an ordinary thermometer and not as a maximum. Holding the thermometer, bulb downwards in a vertical position will generally suffice to set maximum thermometers of this type.

The minimum thermometer should be held vertically, bulb upwards, until the index touches the end of the column of spirit. Tap gently if necessary.

(4.) Test the setting by seeing that the dry bulb, the maximum and the index of the minimum read the same.

Terrestrial Radiation Thermometer.

(*Grass minimum.*)

For estimating the effect of radiation from the earth's surface at night time a minimum thermometer exposed freely on a grass surface is used. To secure greater sensitiveness the wooden mounting of the ordinary minimum thermometer is dispensed with. With the same object various forms of bulb have been suggested. An outer glass case is generally sealed round the stem of the instrument to protect the tube and prevent condensation of the spirit in the upper end.

The thermometer should be supported on two Y-shaped pieces of wood at a height of one or two inches above the ground which should be covered with **short** grass; care should be taken that the bulb does not touch the supports as this would diminish the sensitiveness. The proximity of walls, trees, benches, &c., should be avoided.

When the ground is covered with snow, the thermometer should be supported immediately above the surface of the **snow**, as near to it as possible without actually touching it.

Hour of Reading and Setting.—The hour for reading and setting the grass minimum thermometer raises an important question, The climatic fact which the observations should supply, is the number of nights of ground frost. If 9 a.m. be selected as the hour for setting, it will frequently happen that the reading to which the instrument is set will be the minimum for the ensuing 24 hours, and if the value happens to be below 30° F. (or 30·4° F. if the thermometer is read to tenths of a degree) the statistics may show more "days of ground frost" than there were *nights* of frost.* At stations where evening readings are taken, the thermometer should be read and set at the hour of evening observation. At stations at which observations are taken once a day only, arrangements should be made for *setting* the instrument in the afternoon or evening; the reading may be taken in the morning.

Bubbles in Stem.—The protection of the stem of a grass minimum thermometer by an outer jacket is not always sufficient to prevent the spirit separating into detached portions. During great cold and also when exposed to strong sunshine, grass minimum thermometers are very liable to the development of bubbles in the bulb or stem or to the condensation of drops of spirit in the upper part of the stem. Great care must be taken to avoid errors due to either of these causes. In summer it is advisable to place the instrument indoors during the daytime when the sun is very powerful. It should be kept in a vertical position, bulb downwards, while not in use. Directions for making the spirit column join up again, should it become broken up, have been given on p. 28.

Solar Radiation Thermometer.

(*Black bulb in vacuo.*)

For obtaining some indication of the intensity of the sun's radiation a maximum thermometer having the bulb and one inch of the stem

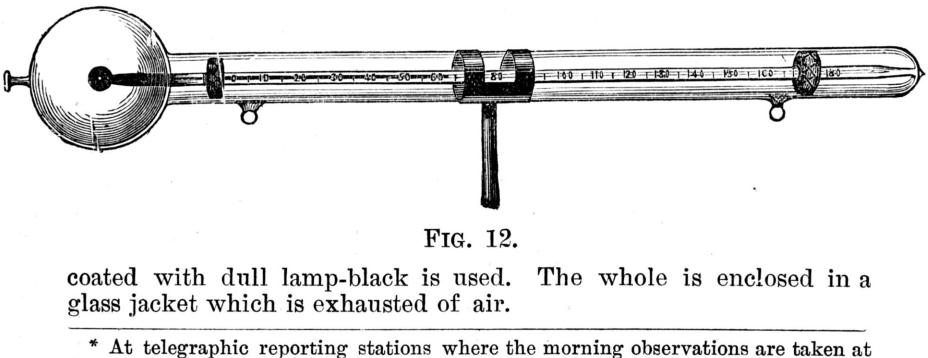

FIG. 12.

coated with dull lamp-black is used. The whole is enclosed in a glass jacket which is exhausted of air.

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* At telegraphic reporting stations where the morning observations are taken at 7 a.m., the number of occasions when this occurs will be even greater than at stations where readings are taken at 9 a.m.

The site for exposure may be near the thermometer screen. The proximity of trees, buildings, &c., must be avoided. The instrument is fixed on a wooden stand at the same height above the ground as the thermometers in the screen (4 feet). The bulb must be freely exposed to the sun, and hence the tube should be directed from East to West.

The difference between the maximum shown by the "black bulb" and the maximum reading in the thermometer screen is usually regarded as an index of the intensity of solar radiation.

Readings are taken once a day only, at 9 p.m. The method of setting is precisely similar to that used in the case of the maximum thermometer. (*See* p. 30.)

Earth Thermometers.

The temperature of the ground is measured by means of thermometers suspended in iron tubes sunk into the earth to the required depth. The depths most commonly adopted are one foot and four feet. The thermometers are enclosed in glass tubes and their bulbs are embedded in paraffin wax so as to render them insensible to sudden changes of temperature. This allows of their being drawn to the surface and read before the temperature has time to change appreciably. As underground changes of temperature are very slow, the loss of sensitiveness, resulting from the coating of wax, does not lead to inaccuracies in the determination of the temperature of the earth.

Water must not collect in the iron tubes; to prevent this the tubes are fitted with small metal covers to which the chains holding the thermometers are fastened. If present, it may be removed by means of a sponge or other absorbent material tied to the end of a stick.

In reading take care to raise the thermometer to the same level as the eye so as to avoid errors of parallax (*see* p. 20), and read to a tenth of a degree as quickly as possible. The instrument should be screened from direct sunshine during the process.

Sea Temperature.

(*a*) At Coast Stations. If possible, select a place where the water is not less than six feet deep at low tide; plunge the thermometer, case and all, one foot under water, and keep it there for three minutes, then take out and promptly read off; *or*, use a canvas bucket and line. Throw the bucket into deep water (not less than 6 ft.), leave for five minutes. Haul in the full bucket. Put the thermometer into the water in the bucket, and after three minutes read the thermometer, holding it upright in the bucket with its bulb and lower part of its stem in the water. Take care to avoid errors of parallax (*see* p. 20).

(*b*) At Ship Station. Draw a bucket of water alongside, place the thermometer in the water for three or four minutes, then, holding the instrument upright with its bulb still immersed, read off.

Hygrometers.

The humidity of the atmosphere is usually determined from readings of dry and wet bulb thermometers placed in a Stevenson screen. The combination of the two instruments is known as a "psychrometer."

A wet bulb thermometer is made by coating the bulb of an ordinary thermometer with muslin kept moist with water. Its action depends on the fact that evaporation takes place from every free water surface as long as the air in contact with it is not saturated with aqueous vapour. The heat required to bring about this evaporation is, in the case of the wet bulb taken in part from the thermometer itself and hence a wet bulb generally reads lower than a dry bulb placed in the same screen. In a saturated atmosphere both instruments should read the same. In unsaturated air the amount of lowering depends on the rate of evaporation, and this in turn on the temperature and dryness of the air.

The relative humidity, dew point, pressure of aqueous vapour &c., corresponding to various readings of dry and wet bulb thermometers are obtained from tables (*see* pp. 123, 144, 150).

Mounting of the Wet Bulb.

The wet bulb thermometer should be covered with a single thickness of thin clean muslin which is kept moist by attaching to it a few threads of darning cotton (No. 8) dipping into a small reservoir of water placed near it. The muslin and thread must be entirely free from grease otherwise they will not keep moist. To remove grease they may be washed in water containing ammonia. Care must be taken that the muslin is stretched smoothly on the bulb, creases must be avoided as far as possible. The muslin may be tied on to the bulb with a cotton thread or it may be secured in position by looping three strands of the cotton used for supplying moisture to the bulb, in the manner shown in the figure. In the case of thermometers with cylindrical bulbs a small "finger" of muslin should be sewn to exactly fit the bulb. After fixing the muslin it should be carefully trimmed with a pair of scissors; all superfluous material and all loose ends should be cut off.

FIG. 14.

The muslin must be clean and must therefore be changed before it gets dirty. In country districts it will generally suffice to change it once a month, but in towns this should be done oftener. The change should be made immediately after or some time before observing. At least 15 minutes should elapse between mounting and reading; if the clean water supplied is not at the temperature of the air, a much longer time is required.

The water used for moistening the wet bulb must be soft; distilled water or rain water is to be preferred. If hard water is used the bulb and muslin become encrusted with a deposit and the readings become inaccurate.

The vessel containing the water supply should be placed below and a little to one side of the bulb of the thermometer. The side remote from the dry bulb should be selected in order that the latter may not be affected by moisture rising from the water. In order to avoid breakage of the water vessel during frost, it should not be filled beyond the line of its widest part.

The part of the cotton thread exposed to the air should be between three and six inches in length, it must be kept as straight as possible. If it be allowed to hang in a loop, water will drip down from the lowest point of the curve until the reservoir is emptied.

The value of the readings depends greatly on supplying moisture to the wet bulb at the proper rate. In warm dry weather there is danger of the water evaporating too rapidly from the conducting threads so that the muslin is left dry and on the other hand, in damp cold weather drops of water may collect on or even drip down from the bulb of the thermometer. Both defects render the reading too high; they may be avoided by adjusting the distance between the thermometer and the water reservoir.

If the reading of the wet bulb is above that of the dry, make sure first that there is no error in reading. Then see if moisture has been deposited on the bulb of the dry. If this is the case, wipe the bulb dry and read again after waiting a minute or two for the thermometer to take up the temperature of the air.

If there is no evidence of moisture, make two or three more observations of both instruments at intervals of about two minutes. It will usually be found in that case that the temperature is falling, and that the wet bulb eventually falls below the dry, although at first the dry may fall more rapidly than the wet.

In the first of these two cases the peculiarity is due to the fact that the dry bulb is acting as a wet bulb, and is giving a temperature below the true air temperature. This will usually happen when temperature is rising. In the second case the wet bulb is lagging more than the dry in air in which the temperature is falling, and the wet-bulb reading is too high.

Management of Wet Bulb during Frost.

The management of the wet bulb during frost or at times when the wet bulb reading is below 32° is troublesome, as the freezing of the water on the conducting threads cuts off the supply of moisture to the muslin. In order to secure satisfactory results the bulb must be coated with a **thin** layer of ice from which evaporation takes place as from water. It is therefore necessary to wet the muslin slightly with **ice-cold** water by means of a camel hair brush or feather, **10 or 15 minutes** before observing. After moistening the muslin the temperature remains steady at the freezing point, 32°, until all the water has been converted into ice, and it then commences to fall gradually to the true wet bulb reading. No reading should be recorded until the temperature of the wet bulb has fallen below that of the dry bulb and become steady.*

The water used must be at the freezing point (it is best taken from under ice), otherwise a very much longer period is required for it to cool. As little water as is consistent with thorough moistening of the muslin should be used. If excess is put on

* After water has been applied, the temperature of the wet bulb may fall considerably below the freezing-point without the formation of ice, the water being supercooled. At the moment of solidification the temperatures rises to 32° F. and then commences to fall again. The temperature finally reached should be entered as the correct wet bulb reading.

not only is the time of waiting much increased, but a thick layer of ice forms on the thermometer which interferes with the accuracy of this and subsequent readings. When this occurs the ice must be removed by immersing the bulb in warmed water.

The amount by which the temperature of the wet bulb is reduced below that of the dry is found to depend to some extent on the ventilation to which the instruments are exposed. On calm days the observer will frequently be able to reduce the temperature of the wet bulb by a degree or more by fanning it. In recent years the necessity of devising a trustworthy instrument for the measurement of temperature and humidity under the special conditions which prevail in balloon ascents has directed attention to this point and has led to the invention by Professor Assmann of the ventilated psychrometer. This instrument consists of dry and wet bulb thermometers mounted in parallel metal tubes which communicate at their upper ends. A small ventilating fan, driven by clockwork is placed in the upper end of the tube. By this means an air current of definite velocity can be aspirated past the thermometers whenever readings are required and comparable results can be obtained.

The Rain Gauge.

Copper gauges are used almost exclusively, on account of their durability. The diameter of the funnel should be either five inches or eight inches. The gauge adopted by the Meteorological Office is eight inches in diameter; its weight varies between $10\frac{1}{2}$ and $10\frac{3}{4}$ lbs. A diagram of the instrument is shown in Fig. 15. The sloping sides of the funnel are six inches below the rim in order to catch snow and diminish the effect of splashing. To prevent deformation, the rim of the funnel is made of a stout ring of brass of which the upper edge is bevelled to prevent splashing. The gauges are now made with a splayed base as shown in the figure. This enables them to be firmly fixed in the ground.

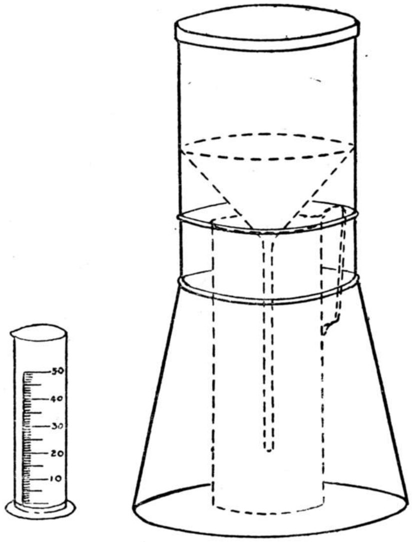

FIG. 15.

Gauges of the Meteorological Office pattern are also made of five inches diameter. The Snowdon pattern gauge, which is also a five-inch gauge, differs from the Meteorological Office pattern in having a straight base and a glass bottle placed within the metal receiver.

Exposure and Fixing.

The amount of precipitation collected by a rain gauge depends to some extent on its exposure and great care must be exercised in selecting a suitable site. The sheltering effect of houses, trees,

bushes, etc., must be avoided or too little rain will be collected. A good working rule is the one already quoted that the distance between the gauge and the nearest object should be at least twice the height of that object.* In most cases the gauge can be placed on the same plot of ground as the thermometer screen at a distance of 10 feet from the latter and on its Southern side. The Southern side is selected as Northerly winds are, in the British Isles, usually the driest, and hence the sheltering action of the screen, if any, is reduced to a minimum when it is to the north of the gauge.

The gauge should be fixed on level ground. Care must be taken that it is firmly secured so that it cannot be blown over in a gale or displaced when the funnel is removed for measuring the rainfall. For this reason the gauges used by the Meteorological Office are now made with a splayed base (*see* Fig. 15), which can be firmly imbedded in the ground.

The gauge should be sunk into the ground so that its rim is one foot above the surface. This height is necessary to prevent water splashing into the gauge, but if it be exceeded it is found that the amount of rain collected decreases owing to wind eddies set up by the gauge itself. The amount of loss depends on the wind force as well as the height above the ground, and no general rules can be given for rendering the records of gauges fixed at different heights above the ground strictly comparable. Wind eddies also render roof exposures inadmissible.

Any thing which decreases the effective area of the collecting funnel reduces the amount of rain collected. Hence it is necessary—

(1) that the top of the gauge be level;

(2) that the rim of the funnel be truly circular.

Measuring.

The rain should be collected in the copper receiver provided for the purpose and not in the glass measuring vessel. If the latter be used, the risk of breakage is increased, especially in winter, when there is danger of frost setting in after rain has collected in the gauge. In the event of the collecting vessel overflowing, the gauge must be dug out, and the water poured from it for measurement. The collecting vessel of the 8-inch gauge will hold four inches of rainfall.

If there is water in the gauge when the collecting vessel is not full, the latter should be carefully examined to see if it leaks.

The hour for measuring the rainfall is at most stations 9 a.m. The gauge should be examined **every morning even in dry weather** as a fall of dew may give rise to appreciable precipitation. Daily examination also acts as a safeguard against errors due to the accidental or even mischievous addition of water.

The water collected should be carefully poured into the graduated glass measuring vessel which must be kept clean. In reading off the amount the vessel should be placed at the level of the eye so as to avoid errors of parallax (*see* Fig. 6, p. 20). The reading should be taken **at the bottom** of the meniscus or curved surface of the water.

The measuring glass will hold ½ inch of rainfall, an amount which corresponds with a weight of 14·50 oz. avoirdupois when collected in an 8-inch gauge or with 5·67 oz. when collected in a 5-inch gauge;

* Mountain, Moorland and Coast Stations. Care should be taken that mountain or moorland gauges are not unduly exposed to the sweep of the wind. A level patch of ground or a slight hollow should be selected.

the measure is graduated to indicate hundredths (·01) of an inch of rainfall and the reading should be given to the nearest hundredth. If the amount be less than one-tenth of an inch, the decimal point and the first "0" should always be entered in the register. Thus, seven-hundredths should be written ·07.

Falls of less than ·01 but more than ·005-inch may be entered as ·01. As the number of rain days depends on uniformity in this particular the ·005 mark is placed on the newer pattern of measuring glasses. Falls of less than ·005-inch should be noted in the register by entering the word "trace." The few drops of water collected may be thrown away.

As the measuring glass only holds ·50-inch of rainfall, heavy falls will have to be measured by instalments. To avoid mistakes in counting the number of half-inches, it is advisable to pour the water into a jug and to check the amount by re-measuring it. If difficulty is experienced in accurately filling the measuring vessel to the graduation ·50-inch it is preferable to fill the glass approximately with each instalment and finally add the readings; thus, ·47 + ·48 + ·49 + ·35 = 1·79 ins.

Snow and Frost.

On days of snowfall or when the water collected in the gauge has frozen two courses are open to the observer :—

(1.) If snow is not falling at the hour of observation, the gauge (funnel and receiver) may be brought indoors, its contents melted and measured in the ordinary way. Excessive heat should not be applied as some loss due to evaporation would occur. Carelessness in warming the gauge before a hot fire has in some cases resulted in melting the solder.

(2.) A definite amount of hot water may be accurately measured into the measuring glass and then poured into the gauge. The amount of water added must of course be subtracted from the total amount measured. If snow is falling at the hour of observation this method should be adopted as it takes less time.

The measurement may be checked by inverting the funnel of the gauge over the snow in a place where its depth seems to be uniform and of about the average amount and collecting the cylinder of snow thus cut out and melting it. This course can only be adopted on occasions when all precipitation has occurred in the solid form. Care must also be taken to collect only the snow which has fallen during the past 24 hours. At some stations a level base of wood is formed for the purpose of measuring the amount of snow. As a rough approximation one foot of snowfall may be taken as equivalent to one inch of rainfall.

The **depth of snow,** determined by plunging an inch scale vertically into the snow where it lies evenly, should be entered in the column provided in the Form for the Monthly Return.

Dew.

If dew has fallen in sufficient quantity to be measurable, the amount should always be measured and entered in the "rainfall" column of the register. A note should be made in the "remarks" column to show that the precipitation took the form of dew. Moisture deposited from fog should be treated similarly.

§ 7. NON-INSTRUMENTAL OBSERVATIONS AND ADDITIONAL INSTRUMENTS.

Wind.

For the complete specification of the wind it is necessary that we should know (1) the direction from which it is blowing and (2) its force or velocity.

Wind Direction.

When recording wind direction, the point from which the wind comes should be stated. The method of specifying directions, and for determining orientation have been described above, *see* pp. 15–17. All directions should be "true" and not "magnetic."

When identifying wind direction the observer must be on his guard against mistaking local eddies due to buildings, trees, &c., for the general drift of air over the station. He may use as his guide the indications of a wind vane or those afforded by the direction of drift of smoke from elevated chimneys, the set of flags, &c.

If a wind vane be used care must be taken :—

(1.) That it is freely exposed on all sides and not affected by local eddies, &c.

(2.) That it moves freely. With most vanes it will frequently happen that the wind is too feeble to move them. Under such circumstances the direction of drift of smoke, &c., must be used for determining wind direction.

(3.) That the cardinal points, if indicated on the vane are correctly set, and that the vane is well balanced, *i.e.*, that it has no bias to set itself in a particular direction.

An excellent wind indicator is furnished by a streamer attached to a tall flagstaff in an open situation.

Whatever mode of observation is used, errors due to perspective are liable to be made unless the observer stands vertically below the indicator.

Wind Force.

Wind force is estimated on the numerical scale ranging from 0, calm, to 12, a hurricane, first adopted by Admiral Beaufort. The explanations originally given by Beaufort for guidance in estimating had reference to a man-of-war of the period 1800-1850. As vessels of this type have become obsolete these instructions now possess little more than historic interest.

The table on pp. 40, 41 is reprinted from a Report* upon "an Inquiry into the Relation between Estimates of Wind Force, according to Admiral Beaufort's scale and the Velocities recorded by Anemometers," which has been issued recently by the Office. It gives the specifications originally drawn up by Admiral Beaufort, and also descriptions of the various wind forces intended to guide the judgment of observers by land and sea.

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* Official No. 180, 1906.

SPECIFICATION OF THE BEAUFORT SCALE

with a table of equivalent velocities in miles per hour for the several numbers based upon the formulae *:—

$$P = \cdot 003\ V^2$$

$$P = \cdot 0105\ B^3$$

$$V = 1\cdot 87\ \sqrt{B^3}$$

Where B is the Beaufort number

V is the corresponding velocity in miles per hour

P the corresponding pressure in pounds weight per square foot.

For the C.G.S. system of units the relations are as follows :—

If F is the force in kilodynes upon a disc one square metre in area facing the wind and V the velocity in *metres per second*

$$F = 72\ V^2$$

$$F = 4\cdot 78\ B^3$$

$$V = 0\cdot 83\ \sqrt{B^3}$$

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* Another example of the representation of an arbitrary scale of numbers by an empirical formula is furnished by a suggestion of Lieut. H. L. D. Craven, R.N., to represent the relation between the height of waves to the number on the conventional wave-scale of the " Instructions for keeping the Meteorological Log." The suggested equation is

$$H = \cdot 05\ C^3$$

Where H is the height of the wave in feet, and C the conventional number. The following table gives a comparison between the scale of wave heights hitherto recommended by the Meteorological Office and the heights calculated by the formula :—

Conventional scale number.	Scale of heights originally recommended.	Heights calculated from the formula.
	Feet.	Feet.
0	0	0
1	—	·05
2	—	·4
3	Under 5	1·35
4		3·2
5	5 to 10	6·25
6		10·8
7	11 to 15	17·1
8	16 to 35	25·6
9	Above 36	36·4 +

Specification of the Beaufort Scale with Probable

Beaufort Number	Admiral Beaufort's General Description of Wind.	Admiral Beaufort's Specification 1805.	Description of Wind.	Mode of Estimating aboard Sailing Vessels.
0	Calm	Calm	—	—
1	Light air ...	Just sufficient to give steerage way.	Light breeze	Sufficient wind for working ship.
2	Slight breeze	That in which a well-conditioned man-of-war, with all sail set and "clean full" would go in smooth water from — 1 to 2 knots.		
3	Gentle breeze	3 to 4 knots.		
4	Moderate breeze.	5 to 6 knots.	Moderate breeze.	Forces most advantageous for sailing with leading wind and all sail drawing.
5	Fresh breeze	That to which she could just carry in chase "full and by." — Royals, &c. ...		
6	Strong breeze	Single-reefed topsails or top-gallant sails.	Strong wind	Reduction of sail necessary with leading wind.
7	Moderate gale (*High wind*)*	Double-reefed topsails, jib, &c.		
8	Fresh gale ... (*Gale*)*	Triple-reefed topsails, &c.	Gale forces	Considerable reduction of sail necessary even with wind quartering.
9	Strong gale ...	Close-reefed topsails and courses.		
10	Whole gale ...	That with which she could scarcely bear close-reefed main topsail and reefed foresail.	Storm forces	Close reefed sail running, or hove to under storm sail.
11	Storm ...	That which would reduce her to storm stay-sails.		
12	Hurricane ...	That which no canvas could withstand.	Hurricane ...	No sail can stand even when running.

* It has recently been decided that for statistical purposes winds of force less than 8 shall not be counted as gales, and to avoid the ambiguity implied by the use of the term "moderate gale" for force 7 the Beaufort description has been modified for use in connexion with the daily weather service by the substitution of the descriptions in italics for forces 7 and 8.

EQUIVALENTS OF THE NUMBERS OF THE SCALE.

Beaufort Number.	Specification of Beaufort Scale. For Coast Use, based on Observations made at Scilly, Yarmouth, and Holyhead.	Specification of Beaufort Scale. For Use on land, based on Observations made at Land Stations.	Mean wind force in lbs. per square ft. at standard density. (P='0105B³.)	Equivalent velocity in miles per hour.†	Limits of Velocity.§
0	Calm	Calm; smoke rises vertically.	0	0	Less than 1
1	Fishing smack* just has steerage way.	Direction of wind shown by smoke drift, but not by wind vanes.	·01	2	1–3
2	Wind fills the sails of smacks, which then move at about 1–2 miles per hour.	Wind felt on face; leaves rustle; ordinary vane moved by wind.	·08	5	4–7
3	Smacks begin to careen, and travel about 3–4 miles per hour.	Leaves and small twigs in constant motion; wind extends light flag.	·28	10	8–12
4	Good working breeze; smacks carry all canvas, with good list.	Raises dust and loose paper; small branches are moved.	·67	15	13–18
5	Smacks shorten sail ...	Small trees in leaf begin to sway; crested wavelets form on inland waters.	1·31	21	19–24
6	Smacks have double reef in main sail. Care required when fishing.	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	2·3	27	25–31
7	Smacks remain in harbour, and those at sea lie to.	Whole trees in motion; inconvenience felt when walking against wind.	3·6	35	32–38
8	All smacks make for harbour, if near.	Breaks twigs off trees; generally impedes progress.	5·4	42	39–46
9	—	Slight structural damage occurs (chimney pots and slates removed).	7·7	50	47–54
10	—	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	10·5	59	55–63
11	—	Vary rarely experienced; accompanied by widespread damage.	14·0	68	64–75
12	—	—	Above 17·0	Above 75	Above 75

* The fishing smack in this column may be taken as representing a trawler of average type and trim. For larger or smaller boats and for special circumstances allowance must be made.

† For converting estimates on the Beafort scale into miles per hour.

§ For finding the Beaufort number corresponding to a velocity expressed in miles per hour. The limits of velocity for *metres per second* are given on p. 42.

It will be noticed that the criteria referred to depend in many cases rather on the effects which the observer perceives on objects round about him than on his own physical sensations. By adopting this method an estimate of wind force may be obtained which is to some extent independent of the observer's actual position. The latter may be comparatively sheltered, but it should be such as to command a good view of a number of objects, by the behaviour of which wind force can be estimated.

Difficulties of exposure frequently render a good estimate of wind force preferable to a measurement with an anemometer. The latter can only record the speed of that portion of the air which passes it, and unless its exposure is satisfactory this may differ greatly from the general speed of the air passing over the surrounding country.

Velocity Equivalents of the Beaufort Numbers.

The question of the velocity equivalents of the Beaufort numbers is one which has claimed much attention. From the nature of the case the estimates of different observers and even the estimates of one and the same observer under different circumstances must vary considerably.

A careful comparison of the Beaufort estimates with the wind velocities recorded simultaneously by anemometers belonging to the Office made in the course of the inquiry referred to above showed that the most probable equivalent hourly velocity for expressing individual estimates in miles per hour or *vice versa* agrees very closely with the results calculated by the formula

$$V = 1{\cdot}87\sqrt{B^3}$$

where V is the wind velocity expressed in miles per hour and B the Beaufort number.

The relation between the wind pressure and the Beaufort numbers is given by the corresponding formula

$$P = {\cdot}0105\,B^3$$

where P is the pressure in lbs. per square foot.

The velocity and pressure equivalents calculated from these two formulæ have been included in the table on pp. 40, 41.

The following table is used in the Meteorological Office for converting wind velocities into Beaufort numbers :—

Beaufort Number.	Corresponding Limits of Velocity.		
	Statute Miles per hour.	Metres per Second.	Feet per Second.
0	Less than 1	Less than 0·3	Less than 2
1	1–3	0·3–1·5	2–5
2	4–7	1·6–3·3	6–11
3	8–12	3·4–5·4	12–18
4	13–18	5·5–8·0	19–27
5	19–24	8·1–10·7	28–36
6	25–31	10·8–13·8	37–46
7	32–38	13·9–17·1	47–56
8	39–46	17·2–20·7	57–68
9	47–54	20·8–24·4	69–80
10	55–63	24·5–28·4	81–93
11	64–75	28·5–33·5	94–110
12	Above 75.	33·6 or above	Above 110.

ILLUSTRATIONS OF CLOUD-FORMS.

Figure.

1. Thread like Cirrus in the Zenith. 1907—July.
2. A tuft of "false" Cirrus. 1910—July 6, 16 h. 55 m.
3. Lenticular mass of Cirro-stratus and Cirro-cumulus with Alto-stratus or Strato-cumulus (with dark shadow) underneath and in front.
4. Cumulus. 1907—June 22, 11 h.
5. Top of Cumulo-nimbus. 1907—June 28, 13 h.
6. Lower part of Nimbus. 1907—May 18, 11 h. 33 m.
7. Veil of Cirro-stratus (Cirrus-haze) with Strato-cumulus in front.
8. Strato-cumulus with alto-cumulus above it. 1909—January 29, 11 h. 45 m.

9–12. Sequence of Cloud-Forms. 1907—February 27, between 14 h. 5 m. and 15 h. 20 m.

13–16. Sequence of Cloud-Forms. 1909—February 4, between 10 h. 40 m. and 12 h. 50 m.

GUIDE TO THE CLASSIFICATION OF CLOUD-FORMS.

For the assistance of observers a scheme of classification of cloud-forms in accordance with the international classification is reproduced on pp. xxviii, xxix, from notes of a course of lectures in the University of London, 1908. It is based upon the consideration of the question whether the observer sees merely the extended under surface of a high distant layer, or of a layer, high or low, immediately overhead (clouds seen mostly in plan), or sees the general mass of the cloud at a distance in perspective (clouds seen mostly in elevation or profile). The height and vertical thickness of the clouds become important items from this point of view. Estimates of the heights of the various types are taken from the International Cloud Atlas. In practice it will be found that many forms of cloud of the British Isles which are not easily classified fall under the denomination *Strato-cumulus* as being seen partly in plan and partly in elevation or perspective but at no great height. Whether the scheme of classification is sufficiently exclusive to make the identification independent of the distance from which the cloud is seen is not yet ascertained.

EXAMPLES OF CLOUD-FORMS.

Photographs by G. A. Clarke, Aberdeen Observatory.

FIG. 1. Thread-like Cirrus in the Zenith. 1907—July.

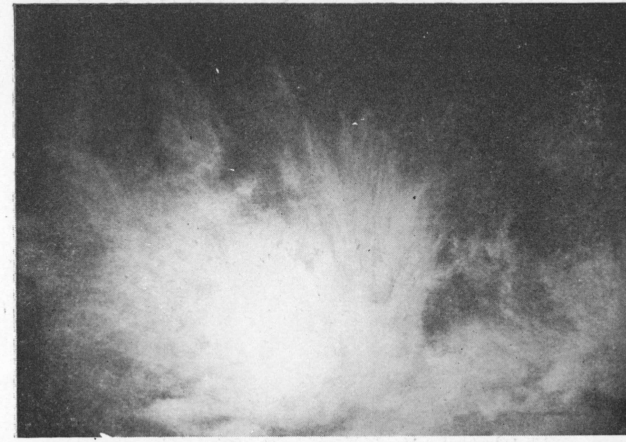

FIG. 2. A tuft of "false" Cirrus. 1910—July 6, 16 h. 55 m.

FIG. 3. Lenticular mass of Cirro-stratus and Cirro-cumulus, with Alto-stratus or Strato-cumulus (with dark shadows) underneath and in front. 1906—Nov. 27, 14 h.

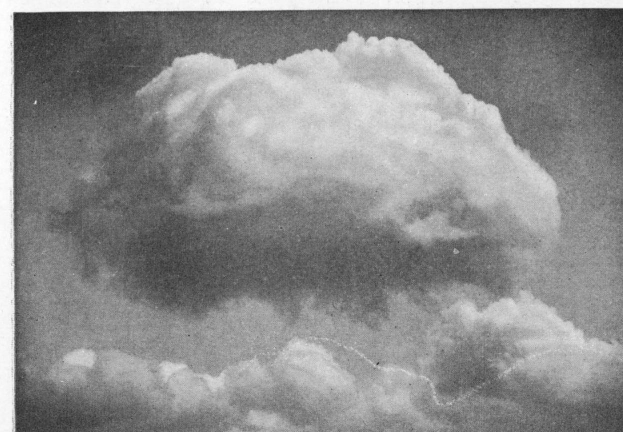

FIG. 4. Cumulus. 1907—June 22, 11 h.

EXAMPLES OF CLOUD-FORMS.

Photographs by G. A. Clarke and Dr. W. J. S. Lockyer.

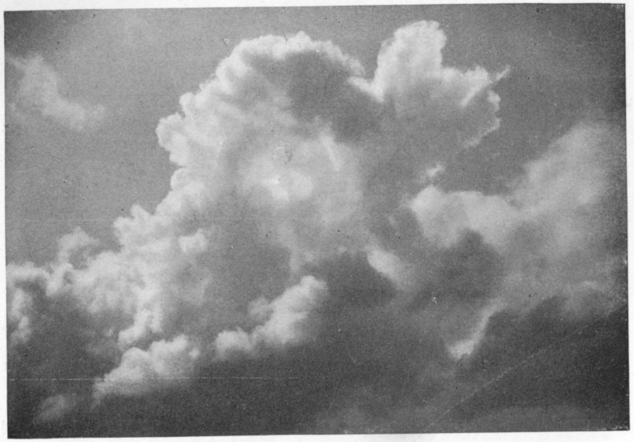

FIG. 5. Top of Cumulo-nimbus. 1907—June 28, 13 h. (G. A. C.)

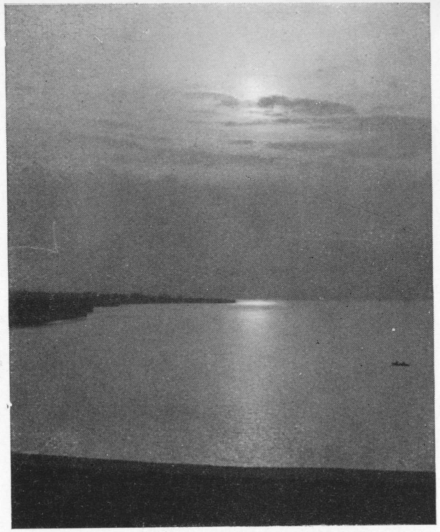

FIG. 7. Veil of Cirro-stratus (Cirrus Haze), with Strato-cumulus in front. (W. J. S. L.)

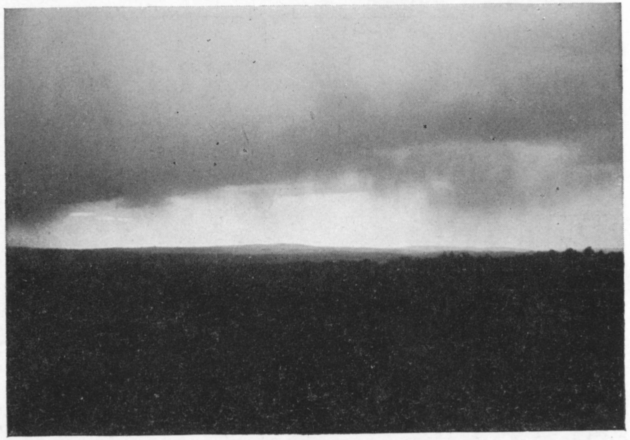

FIG. 6. Lower part of Nimbus. 1907—May 18, 11 h. 33 m. (W. J. S. L.)

FIG. 8. Strato-cumulus with Alto-stratus above. 1909—Jan. 29, 11 h. 45 m. (G. A. C.)

GUIDE TO THE IDENTIFICATION OF CLOUD-FORMS.

Clouds seen mostly in plan

- Stratified in **a** sheet or continuous layer
  - Mean Height 9,000 m. 30,000 ft.
    - Thin veil without shadows (Halo sheet)
      - Tangled Web — *Cirro-stratus*
      - Without structure — *Cirro-nebula*
  - Thick layer grey or bluish, not rainy (Corona layer) 3,000 m. to 7,000 m. 10,000 ft. to 23,000 ft. — *Alto-stratus.*
  - Shapeless Cloud with ragged edges } Below 2,000 m. or 7,000 ft.
    - Rain Cloud — *Nimbus*
    - Rain Cloud with vertical extension — *Nimbus-cumuliformis*
    - **Scud** — *Fracto-nimbus*
- Stratified in separate but ordered cloudlets forming groups (flocks) in layers, lines, or stripes
  - Mean Height 9,000 m. 30,000 ft.
    - Thread or feather clouds — **Mares' tails** — *Cirrus*
  - Height { 10,000 ft. to 23,000 ft. / 3,000 m. to 7,000 m.
    - Small Flocks (Fr. Moutons) in groups or lines, no shadows — **Mackerel Sky** — *Cirro-cumulus*
    - Largish detached masses with some shadow (Fr. Gros moutons) sometimes contiguous in the middle, with detached small flakes at the edges — *Alto-cumulus*
  - Masses with some vertical structure appearing in rolls or waves sometimes covering the whole sky. Below 2,000 m. or 7,000 ft.
    - *Strato-cumulus*
    - **Roll-cumulus**

SEQUENCE OF CLOUD-FORMS. February 27, 1907.

Photographs by G. A. Clarke, Aberdeen Observatory.

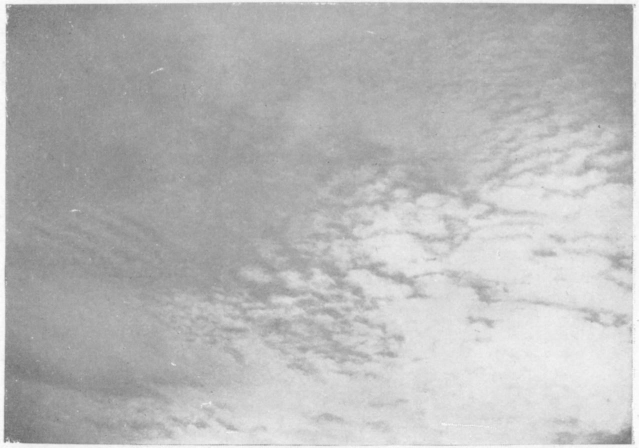

FIG. 9. 14 h. 5 m. Cirrus and Cirro-cumulus.

FIG. 10. 14 h. 10 m. Alto-cumulus.

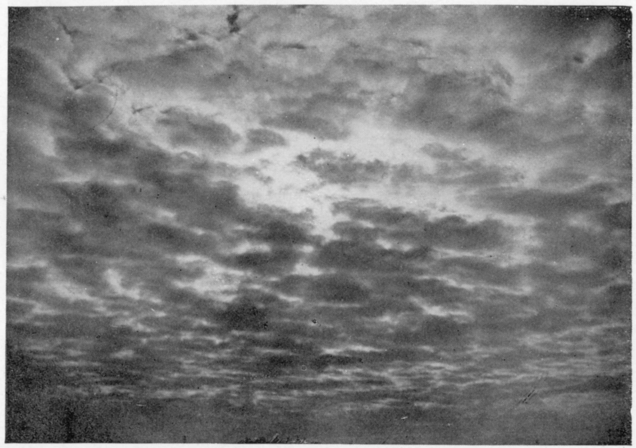

FIG. 11. 14 h. 20 m. Strato-cumulus.

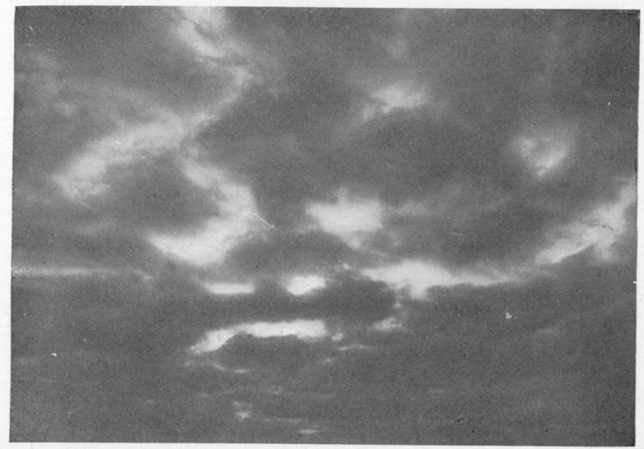

FIG. 12. 15 h. 20 m. Heavy Strato-cumulus.

SEQUENCE OF CLOUD-FORMS. February 4, 1909.

Photographs by G. A. Clarke, Aberdeen Observatory.

FIG. 13. Cirrus and rippled Cirro-cumulus. 10 h. 40 m.

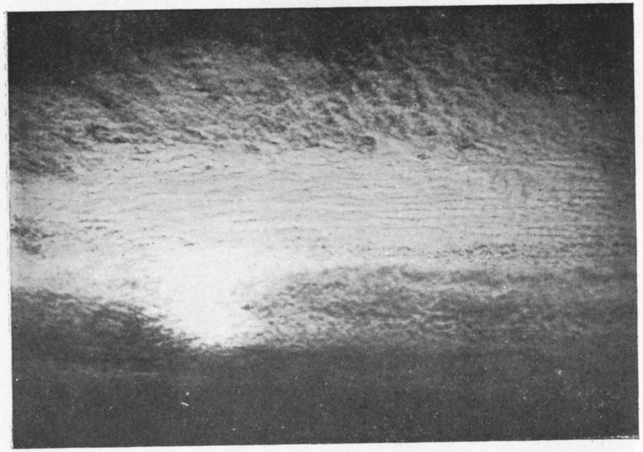

FIG. 14. Rippled Cirro-cumulus. 11 h. 50 m.

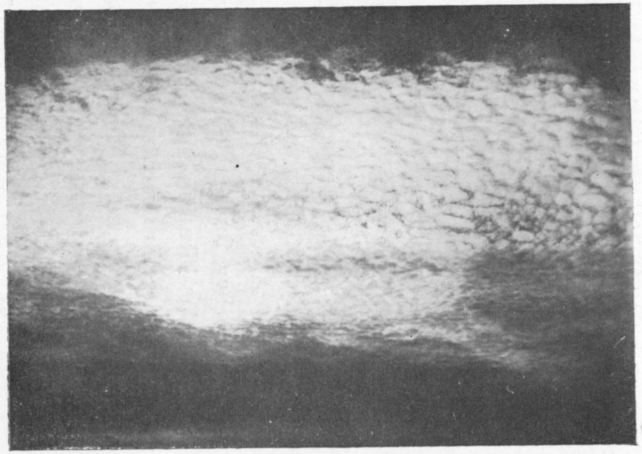

FIG. 15. Cirro-cumulus becoming Alto-cumulus. 12 h. 5 m.

FIG. 16. Alto-cumulus becoming Strato-cumulus. 12 h. 50 m.

NOTE ON THE ILLUSTRATIONS OF CLOUD-FORMS.

The definitions of the typical Cloud-Forms are given in pp. 43 to 45. These definitions are taken from the International Atlas of Clouds which was approved at the International Conference of Directors of Meteorological Institutes and Observatories at Innsbruck in 1905 and published by Gauthier Villars in 1910. It includes a number of carefully selected illustrations of the typical forms reproduced by chromo-lithography, which are intended as a guide to observers as regards the nomenclature of clouds. Copies of the Atlas can be obtained from the Meteorological Office, price 10s.

It was originally intended to make a selection of the illustrations reproduced in the International Cloud Atlas and include copies of them in this volume, but when the Atlas was published it was felt that it would be unjust to the international selection to pick out some and leave others; the international selection must be taken in its entirety as illustrating what the Commission and the Conference meant to be included. Meanwhile it is a matter of common experience that the difficulty of the meteorological observer is not so much in recognising a cloud-form when a typical example occurs as in describing what may be called the every-day sky which is often very composite.

The Meteorological Office has become possessed of a rich collection of beautiful cloud photographs by Mr. G. A. Clarke, of Aberdeen Observatory, showing all kinds of skies, typical and other, for the naming of which the principles of the international classification ought to be an adequate guide. A selection has therefore been made from the photographs included in Mr. Clarke's album and to these names have been given in accordance with the principles of classification laid down in the International Atlas as understood in the Meteorological Office. It is not suggested that the selection includes all the types which an expert meteorologist will recognise.

Clouds.

Cloud observations may be considered under three headings, viz. :—

(1.) Amount.
(2.) Form.
(3.) Direction and Velocity of Motion.

Amount of Cloud.

The proportion of the sky covered by cloud should be indicated on a numerical scale running from 0, cloudless, to 10, completely overcast, in other words we are required to estimate the number of tenths of the area of the sky which would be covered by the cloud present supposing them moved up to each other so as to form a continuous sheet. The numbers given are to refer solely to the amount of the sky covered and not to the density, height or other quality of the cloud.

If desired the density of the cloud may be indicated by adding suffixes 0, 1, 2, thus, 4_1 indicates that rather less than half the sky is covered by moderately heavy cloud, 7_2 that seven tenths are covered by heavy dark clouds.

In estimating, the observer will do well mentally to sub-divide the sky into quadrants by means of diameters at right angles to each other. An estimate (on the scale 0—10) is then formed for each quadrant separately, and the figure finally entered in the register is the mean of the four numbers so obtained.

The direction of the dividing diameters should be selected to give convenient sub-divisions of the prevailing cloud canopy.

Fog must be regarded as a cloud at ground level, and 10 must accordingly be entered for the amount of cloud on foggy days. Some uncertainty arises in the case of mists, or when the sky is obscured by a very thin haze. Supposing that more definite cloud forms are entirely absent, the observer is occasionally confronted by the problem whether he should enter the amount of cloud as 0 or 10. In all such cases appropriate notes should be made in the "remarks" column of the register.

Cloud Forms.*

Luke Howard originally distinguished three principal cloud forms, viz. :—

(1.) Cirrus cloud (of fibrous or feathery appearance, mare's tails).
(2.) Cumulus cloud (having rounded tops).
(3.) Stratus cloud (arranged in horizontal sheets or layers).

Many forms intermediate between these primary types are found to occur, and these are specified by compounding the names of the primary types. As the observation of cloud forms became more common it was found desirable to increase the number of types and to agree on definitions for them. The International Meteorological Committee accordingly, appointed a sub-committee

* A pair of smoked-glass spectacles will be found necessary to avoid over-straining the eyes in observations of clouds.

to prepare and publish an international cloud atlas in which the following classification of clouds into 10 main types has been adopted.

(1.) **Cirrus (Ci.).**—Detached clouds of delicate or fibrous appearance often showing a featherlike structure, generally of a white colour. Cirrus clouds take the most varied shapes, such as isolated tufts, thin filaments on a blue sky, threads spreading out in the form of feathers, curved filaments ending in tufts, sometimes called *cirrus uncinus*, etc. Occasionally cirrus clouds are arranged in parallel belts which cross a portion of the sky in great circles, and by an effect of perspective appear to converge towards a point on the horizon, and if sufficiently extended towards the opposite point also. (Cirro-stratus and Cirro-cumulus are also sometimes arranged in similar bands.)

(2.) **Cirro-Stratus (Ci.-St.).**—A thin whitish sheet of cloud, sometimes covering the sky completely and giving it a milky appearance (it is then called cirro-nebula), at other times presenting more or less distinctly, a formation like a tangled web. This sheet often produces halos around the sun or moon.

(3.) **Cirro-Cumulus (Ci.-Cu.) (Mackerel Sky).**—Small globular masses or white flakes without shadows, or showing very slight shadows, arranged in groups and often in lines. (French, *Moutons*, German *Schäfchenwolken.*)

(4.) **Alto-Stratus (A.-St.).**—A thick sheet of a grey or bluish colour, sometimes forming a compact mass of dark grey colour and fibrous structure. At other times the sheet is thin, resembling thick Ci.-St., and through it the sun and the moon may be seen dimly gleaming as through ground glass. This form exhibits all changes peculiar to Ci.-St., but from measurement its altitude is found to be about one-half that of Ci.-St.

N.B.—The title strato-cirrus is suppressed as giving rise to confusion.

(5.) **Alto-Cumulus (A.-Cu.).**—Largish globular masses, white or greyish, partially shaded, arranged in groups or lines, and often so closely packed that their edges appear confused. The detached masses are generally larger and more compact (resembling strato-cumulus) at the centre of the group, but the thickness of the layer varies. At times the masses spread themselves out and assume the appearance of small narrow or curved plates. At the margin they form into finer flakes (resembling cirro-cumulus). They often spread themselves out in lines in one or two directions.

N.B.—The title cumulo-cirrus is suppressed as giving rise to confusion.

(6.) **Strato-Cumulus (St.-Cu.).**—Large globular masses or rolls of dark cloud, frequently covering the whole sky, especially in winter. Generally St.-Cu. presents the appearance of a grey layer irregularly broken up into masses of which the edge is often formed of smaller masses, often of wavy appearance resembling A.-Cu. Sometimes this cloud form presents the characteristic appearance of great rolls arranged in parallel lines and pressed close up to one another. In their centres these rolls are of a dark colour. Blue sky may be seen through the intervening spaces which are of a much lighter colour (Roll-cumulus in England, Wulst-cumulus in Germany). Strato-cumulus may be distinguished from Nimbus by its globular or rolled appearance and by the fact that it is not generally associated with rain.

(7.) **Nimbus (Nb.)**—A thick layer of dark clouds, without shape and with ragged edges from which steady rain or snow usually falls. Through the openings in these clouds an upper layer of cirro-stratus or alto-stratus may be seen almost invariably. If a layer of nimbus separates up in a strong wind into shreds, or if small loose clouds are visible drifting underneath a large nimbus ("Scud," of sailors), they may be described as *fracto-nimbus.* **(Fr. Nb.)**

(8.) **Cumulus (Cu.) (Wool-pack or Cauliflower Cloud).**—Thick cloud of which the upper surface is dome-shaped and exhibits protuberances while the base is horizontal. These clouds appear to be formed by a diurnal ascensional movement which is almost always noticeable. When the cloud is opposite the sun, the surfaces facing the observer have a greater brilliance than the margins of the protuberances. When the light falls aslant, as is usually the case, these clouds show deep shadows. When on the contrary they are on the same side of the observer as the sun, they appear dark with bright edges.

True cumulus has well defined upper and lower limits. In strong winds a broken cloud resembling cumulus is often seen in which detached portions undergo continual changes. This form may be distinguished by the name *fracto-cumulus.* **(Fr. Cu.)**

(9.) **Cumulo-Nimbus. (Cu.-Nb.) The Thunder Cloud; Shower Cloud.**—Heavy masses of cloud rising in the form of mountains or turrets or anvils generally surmounted by a sheet or screen of fibrous appearance (false cirrus), and having at its base a mass similar to "nimbus." From the base local showers of rain or of snow (occasionally of hail or soft hail) usually fall. Sometimes the upper edges assume the compact form of cumulus, and form massive peaks round which the delicate "false cirrus" floats. At other times the edges themselves separate into a fringe of filaments similar to cirrus clouds. This last form is particularly common in spring showers. The front of thunderclouds of wide extent frequently presents the form of a large arc spread over a portion of a uniformly brighter sky.

(10.) **Stratus (St.).**—A uniform layer of cloud which resembles a fog but does not rest on the ground. If the cloud layer is broken up into irregular shreds in a wind or by mountains, it may be distinguished by the name *fracto-stratus.* **(Fr. St.)**

In view of the almost infinite diversity which cloud phenomena present, the observer must not expect to be able to assign without hesitation all clouds to one or other of the types described. If he is unable to classify the clouds seen, he should note the fact in the register.

If abbreviations be used for the names of the cloud types those given above should be employed.

Several different cloud forms will frequently be present simultaneously. In such cases the direction of motion of each type should be observed in the manner to be described below and noted in the register. The directions of motion of different clouds observed at one and the same time may differ very materially.

Attention is also directed to the following details :—

Undulated clouds.—It often happens that the clouds appear to be arranged in rows like newly ploughed land or like waves on the surface of water. This occurs most frequently with cirro-cumulus, strato-cumulus (roll cumulus), etc. It is important to note the direction of the rows. When two distinct systems are visible with rows in two different directions so that the clouds appear to be made up of separate "flocks," the directions of the two systems should be noted. As far as possible, these observations should be taken of rows near the zenith so as to avoid errors caused by perspective.

The point of radiation of the upper clouds.—These clouds often take the form of narrow parallel lines, which by reason of perspective appear to issue from a given point on the horizon. The "point of radiation" is the name given to the point where these belts or their prolongations meet the horizon. This point on the horizon should be indicated in the same manner as the direction of the wind, N., N.N.E., etc.

The Density and Situation of a Bank of Cirrus.—The upper clouds often assume the form of a tangled web or sheet, which, as it appears above the horizon, looks like a thin bank of a light or greyish colour. It is desirable to note in the "remarks" column of the register :—

(*a.*) The density, for which the following scale is suggested :—

0. Very thin and irregular.
1. Thin, but regular.
2. Fairly thick.
3. Thick.
4. Very thick and of a dark colour.

(*b.*) The direction in which the sheet or bank appears thickest.

Direction and Velocity.

The direction of motion of clouds is always stated as the direction from which the cloud is coming. It is best observed by sighting the cloud against a fixed point. At night time and when the cloud canopy is broken, stars near the zenith form very suitable fixed points. At other times the top of a flagstaff, gable of a house, &c., may be used. If the cloud motion is slow the observer will find it advantageous to rest his head against some fixed support while taking the observation ; otherwise the apparent cloud motion which he observes may be due to motion on his own part. To avoid errors due to perspective he should stand as near as may be vertically below the fixed point and confine his attention to clouds near the zenith. A little experience will enable the observer to give a qualitative statement of the apparent velocity of clouds by means of such designations as slow, moderate, fast, &c.

For the accurate determination of the direction of motion of clouds, some form of nephoscope should be used. These instruments can also be used to determine the angular velocity of a cloud, but the linear velocity cannot be determined with them unless the height of the cloud is known from other considerations.

It is convenient in practice to adopt a measure for the velocity which can be determined easily by observation and which will give the linear velocity directly when the height is known. A

quantity which fulfils both these conditions is the ratio of the horizontal velocity of the cloud to its height. In what follows this will be called the velocity-height-ratio.

It is approximately equal to the angular velocity of the cloud about the point of the earth's surface vertically beneath it. This is greater than the angular velocity of the cloud as seen by the observer except when the cloud is in the observer's zenith.

The two instruments about to be described are so arranged that the velocity-height-ratio is determined directly by an observation which is independent of the distance of the observer from the point vertically beneath the cloud.

Two main types of instrument may be distinguished :—

(1.) Reflecting nephoscopes.

(2.) Direct vision nephoscopes.

Fineman's Nephoscope.

As an example of the first type, Fineman's nephoscope (Fig. 16) will be considered. It consists of a disc of black glass mounted on a

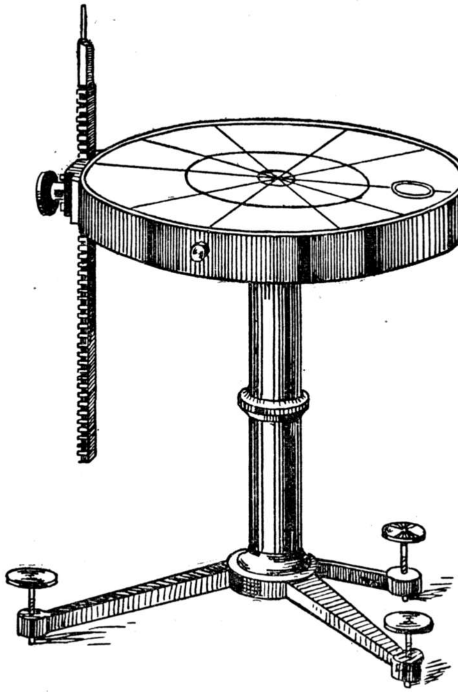

FIG. 16.

tripod stand which allows of accurate levelling. A vertical pointer which can be raised or lowered by a rack and pinion motion is attached to the circumference of the disc in such a manner that it can be rotated about the disc. A scale engraved on the edge of the pointer enables us to read off the height of its tip above the glass surface. On the glass surface three concentric circles are marked, the radii of the two outer circles being respectively twice and three times as great as that of the innermost circle.

The method of observing is as follows:—The observer stations himself in such a position that the image of the cloud in the glass and the central point of the mirror are seen in the same straight line. He then rotates the pointer and adjusts its length until its tip is also brought into this straight line. This done, he moves his head so as to keep the cloud image and the tip of the pointer in coincidence and notes the radius along which the image appears to travel. This radius marks the direction of cloud drift. A compass needle mounted below the disc enables the observer to identify this direction but he must bear in mind that in this country the compass needle points about 18° West of true North (*see* p. 16).

The velocity-height-ratio of the cloud may be determined by noting the number of seconds required for the image to travel from the centre of the mirror to the first circle or from one circle to the next. If a be the radius of the inside circle, b be the height of the tip of the pointer above the reflecting surface and t be the time required for the cloud image to traverse the distance a (both a and b being measured in the same units, *e.g.* millimetres), the value of the velocity-height-ratio as it would appear to an observer at a point on the surface vertically below the cloud is given by the equation

$$\text{velocity-height-ratio} = \frac{a}{bt}.$$

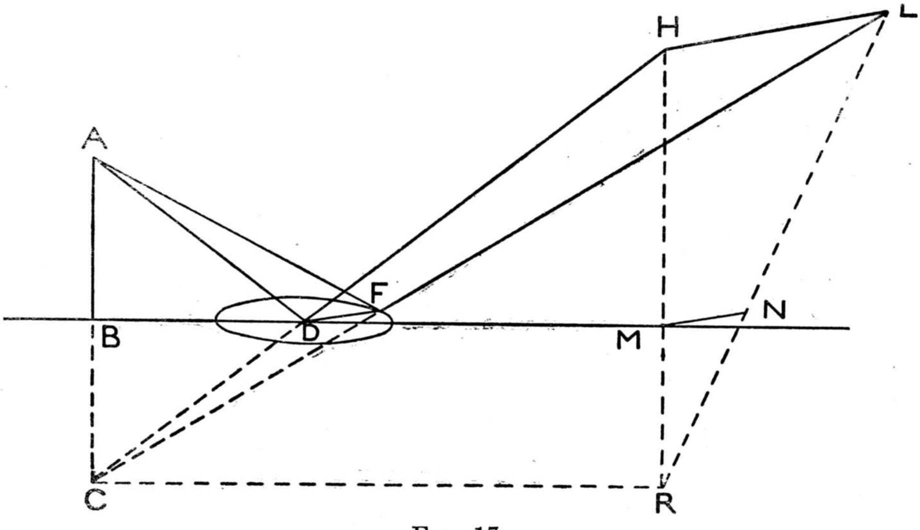

FIG. 17.

Let A B (Fig. 17) represent the pointer, C the position of the image of its tip seen in the mirror, and D the centre of the concentric circles on the mirror. Then A B=B C. Suppose that H L represents the horizontal path of the point on the cloud which is being observed. Then at the commencement of the observation the light from the cloud to the eye passes along the path H, D, A, and at its close it passes along L, F, A. The radius D F is parallel to H L and gives the direction of motion of the cloud.

If R be the point in the horizontal plane through C which is vertically below H, the angular motion of the cloud as seen by an observer at R would be measured by the angle H R L. Let M N be the intercept of this angle on the horizontal plane through the reflecting surface, then it can be shown that

$$MN = DF.$$

The velocity-height-ratio of the cloud =

$$\frac{HL}{t \times HR} = \frac{MN}{t \times MR} = \frac{DF}{t \times BC} = \frac{DF}{t \times AB} = \frac{a}{bt}.$$

Besson's Comb Nephoscope.

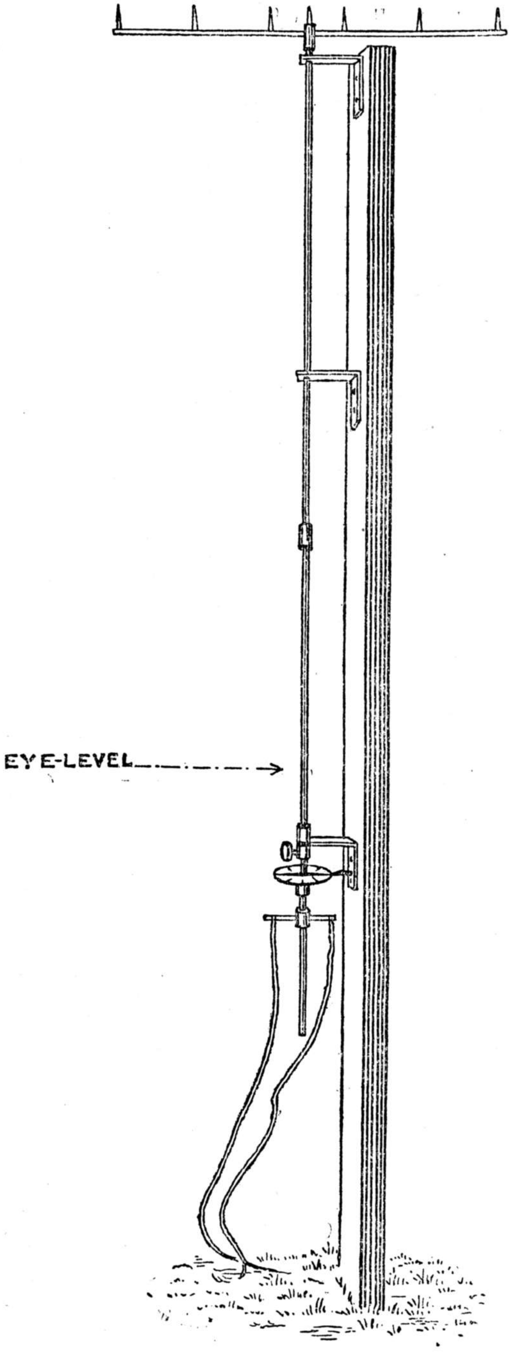

FIG. 18.

Besson's comb nephoscope (Fig. 18.) will serve as an example of a direct vision nephoscope. It consists of a brass rod about 9 feet long, bearing at its upper end a cross piece $3\frac{1}{2}$ feet long, to which a number of equidistant vertical spikes are attached. The rod is mounted in a vertical position by means of a number of rings and clamps screwed into a tall post in such a manner that it can rotate freely. Its height should be adjusted so that a fixed mark on the rod is at the level of the observer's eye.

When using the apparatus the observer stations himself in such a position that the cloud selected for observation is seen in the same straight line as the central spike. He then turns the cross piece until the cloud appears to travel along the line of spikes while he himself remains motionless. The cross piece will then be parallel to the line of motion of the cloud and the direction in which it points can be read off on a graduated circle which is provided for the purpose. The rod may be turned while standing at some distance away from it by means of two cords tied to a second shorter cross piece attached to its lower extremity.

The velocity-height-ratio may be determined by noting the time taken for the cloud to pass from spike to spike. If a be the distance between the spikes, and b the distance from the upper cross piece to the marked point on the rod which has been adjusted to the level of the observer's eye, and t the observed time, we have as before

$$\text{velocity-height-ratio} = \frac{a}{b\,t.}$$

Both a and b must be measured in the same units. The difference in level between the cross piece and the observer's eye should be the same in all experiments and hence the instrument must be set up on a level site. If slow moving clouds are being watched the observer will require a fixed support to steady his head if satisfactory results are to be obtained. He will also need smoked glass spectacles to protect his eyes.

Methods of Stating the Results of Nephoscope Observations.

In stating the results of nephoscope observations one or other of the following methods, which are recommended by the International Commission on Scientific Aeronautics, should be adopted :—

(1.) All clouds are, somewhat arbitrarily, *assumed* to be at a level of 1,000 metres, and the linear velocity, V, is then calculated from the formula

$$V = \frac{a}{b\,t} \times 1000.$$

(2.) The height of the cloud is calculated on the assumption that the linear velocity is 1 metre per second.

If H be this height, we have

$$H = \frac{b\,t}{a} \text{ metres}$$

Weather.

Under the heading "Weather Observations" are classified the various appearances which for the most part indicate modifications in the condition of the aqueous vapour in the the atmosphere, and which are therefore known in some countries under the generic term of "Hydrometeors."

In this country a system of notation devised by Admiral Beaufort consisting, as a rule, of the initial letter of the phenomenon to be indicated has been in use for many years but the Vienna Congress agreed on a system of symbols which should be independent of any language for recording the various phenomena.

The following table gives a list of the letters on the Beaufort notation and the international symbols :—

Intensity may be indicated by attaching "exponents" 0 or 2 to the symbols, thus—$*^0$ means light snow, $*^2$ heavy snow. No exponents other than 0 or 2 should be used with the international symbols.

Beaufort. Letter.	International Symbol.	—
b	...	Blue sky, cloudless.
bc	...	A combination of blue sky with detached clouds.
c	...	Sky mainly cloudy, but with openings between the clouds.
o	...	Completely overcast.
g	...	Gloom.
u	...	Ugly, threatening appearance.
e	...	Wet air, without rain falling.
r	◍ or ●	Continuous rain.
d	●	Drizzle.
s	✱	Snow.
p	●	Passing showers.
h	▲	Hail.
...	△	Soft hail.
...	←	Ice crystals.
...	⊠	Snow on ground.
...	✢→	Snowdrift.
...	⸝⸝⸝	Gale.
q		Squalls.
l	<	Lightning.
t	T	Thunder.
...	Ꞇ<	Thunderstorm.
f	≡	Fog.*
fe	≡:	Wet fog.*
m	≡°	Mist.*
...	≡	Ground fog.
z	∞	Dust haze.
w	⌓	Dew.
x	⊔	Hoar frost.
...	V	Rime.

* Wavy lines were used for many years in the publications of the Meteorological Office to represent fog or mist.

Beaufort Letter.	International Symbol.	—
...	∼	Glazed frost.
v	...	Unusual visibility of distant objects.
...	⊕	Solar halo.
...	⦶	Solar corona.
...		Lunar halo.
...		Lunar corona.
...	⌒	Rainbow.
...		Aurora.
...		Zodiacal light.

Appearance of sky.—b, bc, c, o. These letters are intended to refer only to the amount of cloud visible and not to its density, form, or other quality. They have gradually come to be regarded as corresponding to the following cloud amounts in the scale 0–10 :— b = 0 or 1, bc = 2 to 4, c = 5 to 8, o = 9 or 10. The letters g and u which stand respectively for gloomy and threatening (ugly) should be used when appropriate to indicate the general appearance of the sky.

Precipitation.—A distinction is drawn on the Beaufort notation between steady rainfall (letter r), light drizzle (letter d), and passing showers (letter p). The international symbol ● is used for all three letters r, d, p, of the Beaufort notation, but the indication of passing showers is useful, and the time of commencement and ending of heavy showers should always be noted. The letter e has been added recently to the Beaufort system to indicate a state in which the air deposits water copiously on exposed surfaces without "rain" falling.

Unless otherwise stated, it is assumed that the letter p refers to showers of rain. Snow or hail showers may be noted thus, sp, hp; showers of mixed hail and rain thus, rhp. No separate letter is given for sleet; the combination rs is generally used.

Hail.—The international symbols distinguish between true hail ▲ and soft hail △. In the former the stones are hard, and occasionally of considerable size, in the latter they are small and soft, resembling little snow pellets. The German and French terms for soft hail are "graupel" and "grésil" respectively.

The following working definition of hail was adopted by the Congress of Vienna for the purpose of computing the number of days of hail. "Hail may be defined as a precipitation of frozen water in which the stones attain such a magnitude that they may be expected to do damage to agricultural products." In preparing statistics for British stations it has been customary to count all days on which hail

was observed as "days of hail" even though the stones were small and few. The days to which the international definition applies should be specially noted in the Register.

Ice crystals. ← Small crystals of ice occasionally fall in winter. They may be distinguished from hail or snow by their shape and size.

Snow on ground. ⊠ The symbol should only be used when one half or more of the country surrounding the station is covered with snow at the hour of morning observation. The depth of the snow, determined by plunging an inch measure vertically into the snow in a place where it is lying evenly, should be entered in the column provided or in "remarks." The mean of measurements made in several different places should be given.

Fog, f ≡; **Mist,** m; **Haze,** z ∞. These three words are used to indicate a deterioration of the transparency of the lower layers of the atmosphere caused by solid or liquid particles, and in ordinary literature the choice of the particular term employed is almost at the discretion of the writer.

"Mist" and "fog" both refer properly to surface cloud; in either case there will be little or no difference between the readings of the dry bulb and wet bulb thermometers. In smoky districts the term "fog" is employed unless the cloud is unusually white. In country districts either term is used. A slight fog is sometimes called a haze, but it is better to restrict the use of the word haze to the obscurity due to smoke, dust or other cause when the air is dry and there is considerable difference between the dry bulb and wet bulb readings. In London and other cities the word "fog" is used to describe the smoky surface cloud which persists when the air is calm and dry. The term "thick haze" would be more in accordance with the definitions given here, but the word fog is too commonly used for it to be replaced in that special sense. At the telegraphic reporting stations the letter *z* has been introduced to indicate "haze."

Endeavours have been made to draw a distinction between "mist" as a cloud on the surface which wets objects exposed to it, and "fog" as being one in which objects remain dry. The distinction is, however, not a practical one, having regard to the established usage of travellers on land and sea. Occasions on which moisture is deposited copiously on exposed surfaces without rain falling should be noted among the "remarks."* Fog seems always to imply inconvenience to travellers, and thus the word may be used to denote the obscurity of the atmosphere regarded not from the point of view of the meteorologist, but from that of the wayfarer. The same cloud may be a "fog" for a person who loses his way in it, but a "mist" for a person looking at it from a distance. The distinction is an important one in the practical applications of meteorology and fog should therefore be understood to mean surface cloud regarded from the point of view of interference with traffic.

A numerical scale of five steps of fog intensity, based on this criterion, was adopted in an inquiry into the occurrence and distribution of fog in the London area during the winter 1902–3. The

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* See p. 54 under "Wet fog."

following is a reproduction of this scale as modified by subsequent experience :—

—	—	On Land.	On Sea.	On River.
No Fog or Mist.	0 *f.*	Horizon clear ...	Horizon clear ...	Horizon clear.
Slight Fog or Mist. $\equiv^{0}$	1 *f.*	Objects indistinct, but traffic by rail or road unimpeded.	Horizon invisible, but lights and landmarks visible at working distances.	Objects indistinct, but navigation unimpeded.
Moderate Fog	2 *f.*	Traffic by rail requires additional caution.	Lights, passing vessels and landmarks generally indistinct under a mile. Fog signals are sounded.	Navigation impeded, additional caution required.
	3 *f.*	Traffic by rail or road impeded.		
Thick Fog $\equiv^{2}$	4 *f.*	Traffic by rail or road impeded.	Ships lights and vessels invisible at ¼ mile or less.	Navigation suspended.
	5 *f.*	Traffic by rail or road totally disorganised.		

When the obscurity does not interfere with traffic it may be identified as mist, and thus mist may be regarded, in a sense, as slight fog and fog as thick mist.

In counting "days of fog" (see p. 65) only those days should be included on which intensity 2 *f* on this scale is reached or exceeded, for in larger cities during the winter there is nearly always obscurity of the atmosphere enough to justify an entry of intensity 1 *f.* To facilitate the preparation of statistics the use of the international symbol ≡ or of the word "fog" without a qualifying adjective such as "slight" should be restricted to cases of moderate or thick fog.

Fog (or mist) should only be entered without qualifying remarks on occasions when the observer is entirely surrounded by it. If fog is observed at a distance an entry should be made in the "remarks" column after the following manner :—"Fog in valley, sunrise to 11 a.m." or "Wreaths of fog (mist) in meadows, evening." Such days should not be counted as "days of fog."

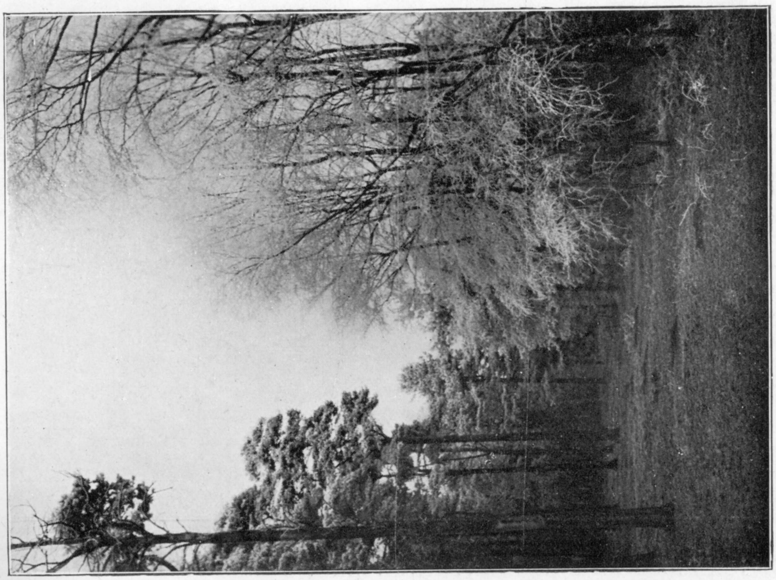
Wet Fog. ≡⁝ A fog in which water is deposited copiously on exposed surfaces should be noted by means of the letters *fe* or by the symbol given above, which is a combination of the symbol for fog with ⁝, formerly used to indicate rainfall.

Ground Fog. The use of this symbol to indicate a ground fog, *i.e.*, a fog which does not exceed the height of a man, has received international sanction. Fog in a valley seen from a station on a higher level should not be entered as a "ground fog."

Dew. Moisture condensed from the atmosphere on exposed surfaces. It is caused by the loss of heat from blades of grass, shrubs, roofs, &c., by nocturnal radiation and consequent cooling below the temperature at which the water vapour present in the atmosphere is sufficient to saturate it. The symbol represents a dew-drop.

To face page 54.

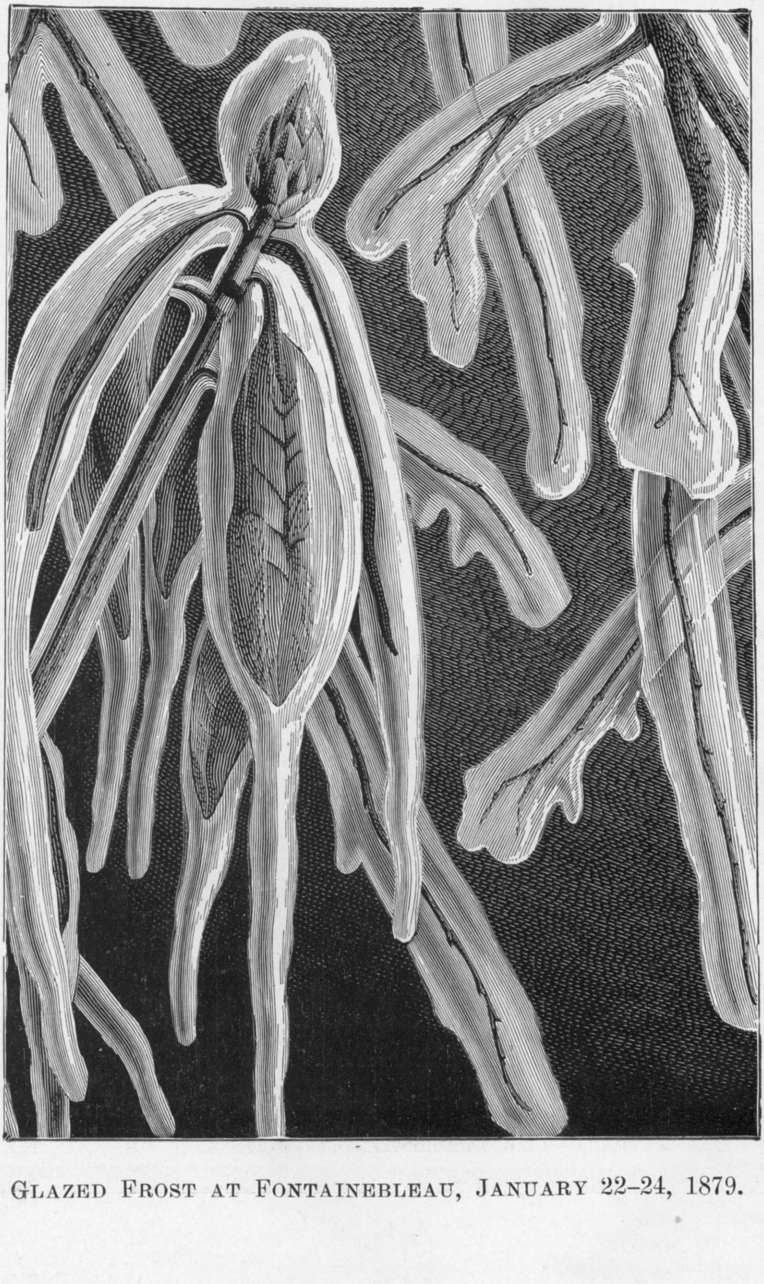
PLATE I.



RIME, NEAR HOLMES CHAPEL, CHESHIRE, JANUARY 5TH, 1908.

To face page 55.

PLATE II.



GLAZED FROST AT FONTAINEBLEAU, JANUARY 22–24, 1879.

Hoarfrost, Rime, Silver-Thaw,* Glazed Frost.—Different writers have used these terms with different meanings and some confusion has in consequence arisen in the method of using the symbols. The following explanations are based on the descriptions of the phenomena given in Hann's "Lehrbuch der Meteorologie" (Ed. 1906 pp. 189 *et seq*).

Hoarfrost. ⊔ (German *Reif*, French *rosée blanche.*) Hoarfrost resembles dew in the manner of its formation. When the temperature falls sufficiently low the water vapour may be deposited in the solid state or the dew originally deposited in the liquid state may become frozen. The deposit thus formed is hoarfrost. It presents a white crystalline appearance but the particles have been shown to be amorphous in structure in most cases.

Rime. **V** Plate I. The international symbol **V** is intended to represent the phenomena denoted by the German words *Rauhreif*, *Rauhfrost*, *Anreim*, *Duft*, and the French *Givre*. Silver Thaw has been used as the English equivalent of these terms by some writers, others however use this expression to translate the German "Glatteis," French "verglas." It is here proposed to use the word rime to translate the German "Duft," French "givre."

Rime, as thus defined, is an accumulation of frozen moisture on trees, &c., which presents a silvery white and **rough** surface, bearing some resemblance to hoarfrost; it is, however, **only formed during fog** whereas hoarfrost is a result of nocturnal radiation from the earth to a clear sky.

In our climate rime is of comparatively rare occurrence, for the white deposit on grass, &c., observed on foggy mornings, consists in most cases of hoarfrost which had formed before fog developed. On Ben Nevis the depositions, however, were frequently so thick that they greatly interfered with the work of observing by clogging up the louvres of the thermometer screen, &c. The phenomenon was noted in the record under the name "fog crystals."

The particles in a fog, even at temperatures far below the freezing point, consist of droplets of super-cooled water and when these come in contact with bodies they solidify immediately, and form rime. Hoarfrost and rime may be distinguished, to a certain extent, by the fact that the former is not readily formed on good conductors of heat in thermal contact with relatively warm bodies on which they can draw for a supply of heat to replace that lost by radiation, whereas rime is deposited on all with equal facility.

Glazed Frost. ~ (German *Glatteis*, French *verglas.*) Plate II.

A transparent **smooth** coating of ice covering trees, buildings, etc. The phenomenon is usually caused by rain which freezes as it reaches the ground and thus covers all objects with a coating of smooth transparent ice. It is very rare in our climate, but on the Continent or in America it is more common. The weight of the ice which collects is frequently sufficient to cause damage to telegraph wires, trees, &c. It is probable that the rain in these cases consists of supercooled drops of water.

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* "Silver-thaw," is apparently a term that has come into use in America without any precise definition.

Glazed frost can also occur when a warm moist air current sets in suddenly after intense cold. The moisture of the air may then be condensed on cold surfaces and cover them with a thin layer of ice.

As has already been stated the term "silver thaw" has been used by some writers as the equivalent of "verglas" and "glatteis," but others use it to indicate what we have called "rime." The confusion has no doubt been considerably aided by the comparative rarity of both phenomena in our climate. The illustration reproduced in Plate II. (*see* Tissandier, "l'Ocean aërien") shows a typical case of glazed frost. It may, however, be pointed out that as both are probably caused by supercooled water drops, which differ only in size or in degree of supercooling, the two phenomena may merge gradually one into the other, and as a matter of fact in many of the descriptions given by continental writers, it is expressly stated that the two phenomena occur side by side.

Some of the appearances of a glazed frost may be produced when frost sets in suddenly after a partial thaw of snow. This is however a combination of circumstances which does not call for a special meteorological symbol.

Thunder T. Lightning <. Thunderstorm Ꝁ. The combined symbol Ꝁ should be used to indicate a true thunderstorm which may be defined as an occasion of both thunder and lightning. On occasions when thunder alone is heard the symbol T should be used.

The lightning symbol < when used alone, stands for sheet lightning (lightning without thunder).

The times at which thunderstorms occur should be given in the "remarks" column; it is desirable to note the time of commencement of a thunderstorm, as given by the first thunder, and the time of the more prominent flashes to the nearest minute. The direction from which the thunderclouds approach should also be noted.

Gale. The occurrence of winds of force* 8 or above, should be noted in the "remarks" column by means of this symbol. The number of barbs on the arrow may conveniently be made to represent the strongest wind force noted. The times of commencement, abatement and greatest violence of the gale should be stated.

Visibility.—v. This letter is used to indicate unusual transparency of the atmosphere, whether the sky be cloudy or not.

Optical Atmospheric Phenomena.

The following instructions for observing optical atmospheric phenomena are translated from the instruction drawn up by the late Professor J. M. Pernter and incorporated in the Handbook issued by the Austrian Meteorological Department. They received the approval of the International Conference of Directors of Meteorological Institutions which met at Innsbruck in 1905.

There are a large number of optical phenomena which not only arrest the attention of observers on account of their beauty, but also

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* It has recently been decided that for statistical purposes winds of force less than 8 shall not be counted as gales, and it is therefore requested that the symbol and the word "gale" will not be used to designate winds of less force than 8. To avoid confusion the term "moderate gale" has been omitted from the specification of wind force given on pp. 40, 41. (Report of the International Meteorological Committee, Berlin, 1910, 5th sitting and Appendix XIV.)

are more or less closely connected with the weather; they are of importance for both reasons, and observers are recommended to note them carefully.

Halo. Solar Halo ⊕; Lunar Halo Ⓤ.—Many different kinds of halo have been observed (*see* fig. 19*). The most common is the halo of 22°—a large ring, CIBG, round the sun or moon, having a radius of very nearly 22° (of a great circle). When of no great intensity the ring appears white, but when it is more strongly developed we may easily recognise the fact that the edge nearest the

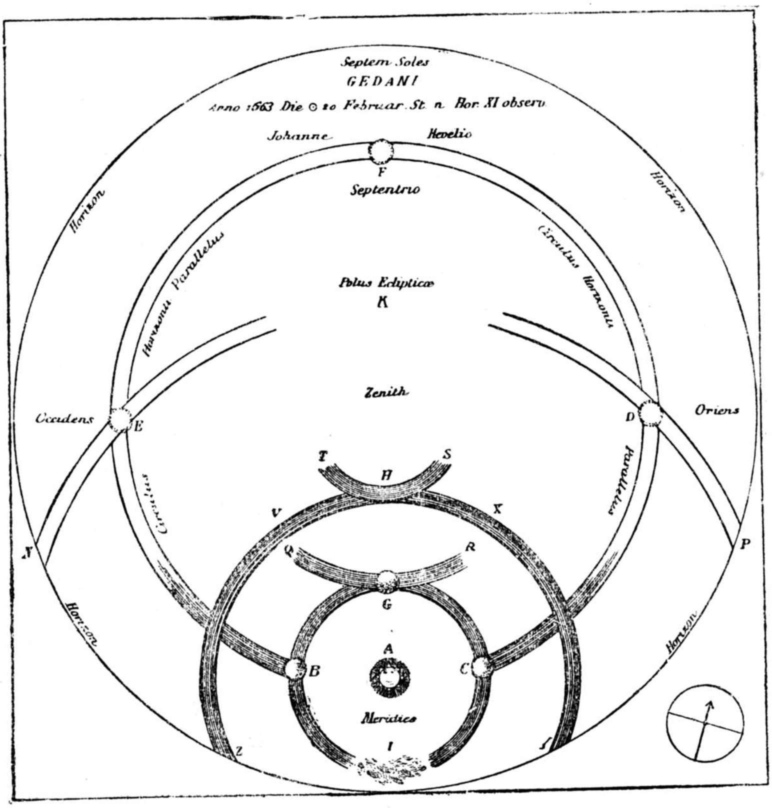

Fig. 19.

sun is red—a very pure red—and that orange, yellow, and, under very favourable circumstances, green, follow on, as we go outwards. The latter colour is always rather faint and whitish, and the blue is almost always so faint that it is not recognised as blue. Violet is never recognisable. The ring thus appears white on its outer edge.

A ring of about twice the radius, halo of 46°, Fig. 19, VXYZ, occurs more rarely. Its luminosity is much less than that of the halo of 22°; the arrangement of the colours, if visible, is the same.

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* Fig. 19 is a representation of the so-called Danzig phenomenon, as seen, drawn, and described by the well-known astronomer Hevel. The date of the observation is shown at the head of the figure. This figure is a facsimile of the original in Hevel's Publication (*see* Hellmann, "Neudrucke, Meteorologische Optik," p. 57).

Occasionally a colourless white ring, which passes through the sun parallel to the horizon, may be recognised. This is called the horizontal circle or mock sun ring. The latter name has been given to it because the mock suns described below lie on or near it. It is represented in the figure by the circle CDFEB, in which the portion BC, which passes through the sun, is omitted. This is frequently the case, but there are many cases on record in which the portion passing through the sun was distinctly visible.

A fourth ring is exceedingly rare; it is white, and has a radius of about 90°; it is known as the halo of 90°. In the diagram two portions of it, NE and DP, are visible; if produced they would pass through K. It is obvious that this halo can never be seen in its entirety in our latitudes, for this would require the sun to be in the zenith.

It should be mentioned that the rings are frequently incomplete in the cases of the three first-mentioned halos also; at times only small portions of them can be seen.

There are a number of other halo phenomena which, from their method of formation, can only be seen as arcs. Among these are the so-called *arcs of contact*, of which two are shown in the figure. Both of them are arcs of upper contact, RGQ belonging to the halo of 22°, THS to that of 46°. Arcs of lower contact may occur in connexion with both these rings, but they are very rare. The arcs of upper contact appear with their convex sides turned towards the sun, as shown in the figure. Contact arcs appear occasionally at the sides of the halos of 22° and 46°, but they are as rare as the arcs of lower contact. The arcs of upper contact are very luminous at the points of contact, which have occasionally been described as "mock suns." The colour effects are often brilliant, red being turned towards the sun, *i.e.*, on the convex edge of the halo. The coloration of the arc of upper contact of the halo of 46° is frequently exceedingly brilliant. The ends of the arc of upper contact of the halo of 22° are frequently bent downwards.

A large number of other rings and arcs have been observed on rare occasions, and are generally described as "irregular"; observers who are fortunate enough to see such irregular bows are requested to sketch and describe them carefully, and, if possible, **to measure their angular distance from the sun.**

Of all halo phenomena, mock suns (parhelia) and mock moons (paraselenae) are probably the most admired. These terms are used to describe luminous, or even brilliant images of the sun which are seen most frequently at or near the intersection of the halo of 22° with the white mock sun ring (B and C, fig. 19). Very rarely mock suns are seen at or near the intersection of this ring with the halo of 46°. The mock suns of this halo are always very faint, and their colouring is indistinct; mock suns belonging to the halo of 22° are, on the other hand, both frequent and very luminous, and their colours are brilliant. Red is on the side nearest the sun, with yellow, green, and blue following in order. Blue is generally indistinct, and violet is usually too faint to be distinguished. As a rule a long and pointed white tail, occasionally attaining a length of 20°, extends from the mock suns along the mock sun ring (*see* fig. 19).

The mock suns of the ring of 90° (D and E, fig 19) have been observed on a few occasions only since Hevel's day.

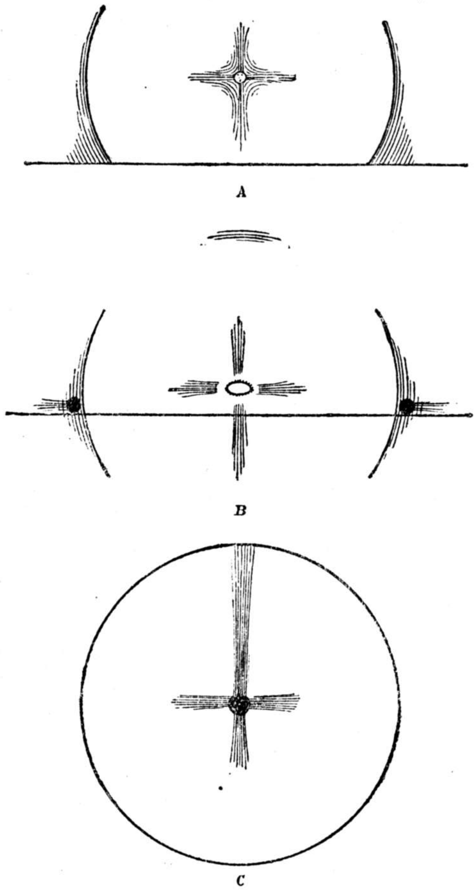

FIG. 20.

Not infrequently mock suns are seen without any of the rings being observed.

A white brilliant image of the sun is occasionally observed immediately opposite to it, *i.e.*, 180° away from the luminary along the mock sun ring. This is known as the counter sun. Mock counter suns, at about 60° along the mock sun ring from the counter sun, have been repeatedly observed, and their distances from the sun have been measured.

Other mock suns, besides those which have been mentioned, are occasionally seen. Observers are requested to sketch and describe what they see carefully, should they happen to observe one of these. If possible they should determine its position by measurement.

Other very beautiful halo phenomena are afforded by *sun pillars*, which are most easily observed at sunrise or sunset. These frequently extend about 20° above the sun and generally end in a point. At sunset they may be entirely red, but as a rule they are of a blinding white and show a marked glittering. If the sun is high in the heavens, white bands may appear vertically above and below him, but these are not very brilliant and often they are very short.

Occasionally these white columns appear simultaneously with a portion of the white mock sun ring, and so form another very remarkable phenomenon, viz., the cross (Fig. 20).

Frequently parts only of the rings and arcs are visible, having apparently no connexion with one another, thus lending a very peculiar appearance to the sky: not infrequently these arcs intersect obliquely, which increases the strangeness of the appearance.

Many other halo phenomena are known to occur, but the space which can be devoted to the subject in a book of instructions to observers is limited, and they cannot all be described here. All halo phenomena should be carefully sketched and described.

Halos only occur in presence of cirrus clouds or of light ice fog; they are produced by refraction and reflection of the rays of the sun or moon by ice crystals. The sun has been assumed as the source of light in all the phenomena described. This has been done solely for the sake of brevity; precisely similar though rather less brilliant appearances may be produced by moonlight.

Corona. Solar Corona ⦶; Lunar Corona ⨀.—Coronae are seen most frequently round the moon. As their diameter is generally considerably smaller than that of the halo of 22° they are very near the luminary and can thus only be seen around the sun under favourable circumstances. No doubt they occur round the sun as frequently as round the moon; they may be observed by making use of a reflector or of a smoked glass to reduce the intensity of the light.

Coronae are very different from halos. The latter are produced by refraction, whereas the former are diffraction phenomena. The positions and orders of the colours serve to distinguish the two sets of phenomena. Coronae invariably show a brownish red inner ring, which, together with the bluish-white inner field between the ring and the luminary, forms the so-called *aureole*. Frequently, indeed very frequently, the aureole alone is visible. The brownish red ring is characteristically different from the red ring of a halo; the former is distinctly brownish, especially when the aureole alone is visible, and of considerable width, whereas the latter is beautifully red and much narrower. If other colours are distinguishable, they follow the brownish-red of the aureole in the order from violet to red, whereas the red in a halo is followed by orange, yellow and green. The order of the colours is thus reversed.

The size of the diameter of the ring has been erroneously suggested as a criterion for distinguishing between halos and coronae, but a corona may be quite as big as a halo. Bishop's ring* has furnished a well-known example of such a corona. The criteria which the observer should apply to distinguish the two sets of phenomena are not the diameters of the rings, but the sequence of colour and the presence of the brown-red of the aureole.

As coronae are diffraction phenomena they occasionally show the sequence of colour two or three or even four times over. This can never be the case with a halo. Observers are requested to note carefully the colours which they can identify and also the order in which they follow one another from the inside to the outside of the ring.

In a foggy atmosphere (especially on mountains) an observer, standing with his back to the sun, will sometimes see a coloured

* In the year following the eruption of Krakatoa (1883) and again in 1903 after the eruption of Mount Pelée, a brownish red ring of over 20° diameter was frequently seen with a clear sky. It was proved to be an unusually large corona.

ring of light round the shadow cast upon the fog by his own head. This appearance has been variously called "glory," "Ulloa's ring," "Brocken spectre," etc.

Green and red patches are occasionally seen in cirrus clouds, at a great distance from the sun or moon. They have no apparent connexion with coronae and may even occur when no corona is visible. Frequently a number of these patches may be seen along a line passing through the sun. This phenomenon is known as "irisation." The most important point to note is the (angular) distance between the sun (or moon) and the patches showing irisation.

Rainbow ⌒.—The erroneous assumption that all rainbows show the same sequence of colours and have the same radius has caused the careful study of this phenomenon to be much neglected. It has been shown that the colours of a rainbow as well as their extent and the position of the greatest luminosity are very variable and depend on the size of the drops producing the bow. It is very desirable that greater attention be given again to this subject. If we note (1) the sequence of colours seen in the primary bow commencing with the red, (2) the colour which shows the maximum luminosity, and (3) which colour band is the widest, we can in most cases calculate the size of the drop producing the bow. This can be done with greater certainty if the observer also pays attention to the supernumerary bows which frequently appear on the inner side of the primary bow, and (1) notes the sequence of colours in them, and (2) states whether the bows are continuous with the primary bow and with one another.

Observation should also be made of the secondary bow which appears outside the primary bow at a distance of about 12° from it. This bow is of less importance, if the primary bow is visible.

Coloration of the Sky.—A cloudless sky appears to be blue, but it may show all possible gradations between a deep blue and a whitish-blue shade. It is desirable to note the gradations of colour according to the scheme ; deep blue, light blue, and pale blue. Such observations give information regarding the purity of the air, and may also be used as indications of coming weather.

The most beautiful colours are seen at dusk. When the sky is cloudless, the colour and form of the first "purple light" is worth attention. It is approximately parabolic in shape and appears at a considerable elevation above the point where the sun disappeared soon after sunset.* It varies in colour between pink and violet. Observers are also invited to note the colouring of the western sky and the appearance of the "second purple light" which develops after the disappearance of the first. The time of disappearance of the second light is also of importance. If "Alpenglühen" and "after glow" are associated with the sunset, the phenomena should be noted.

The coloration of the clouds at sunset is often very beautiful and very striking, and is therefore frequently noted, although the phenomena observed when the sky is clear are more important.

Aurora.—The Aurora usually appears as a bright arch beneath which the sky seems to be darker than in the surrounding regions. Frequently streamers of light shoot out radially from the arch and sometimes extend beyond the zenith. Occasionally the arch resembles a swaying sheet or curtain of light, and at times several arches can be seen simultaneously.

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* All these remarks apply also to sunrise but in the reverse order.

Observers should note such points as the direction in which the phenomenon appears most intense, the direction of the arches and their angular height above the horizon, the length and position of the most prominent streamers, &c. Attention should also be directed to the colour effects visible.

The Aurora is an electrical phenomenon and is usually associated with magnetic storms.

Zodiacal Light. This phenomenon is generally confined to the region between the Tropics, but under exceptionally favourable circumstances it may be seen in our latitudes also. It shows as a faint light rising from the horizon in the form of a pyramid of which the central line lies along the Zodiac. It is most easily seen in spring (in the evening) and in autumn (in the morning).

§8. THE PERMANENT REGISTER.

(Meteorological Office, Form No. 355.)

The observations entered in the rough book should be copied in *black ink* on to the forms supplied for the purpose by the Office. These forms are arranged on similar lines to the form adopted by the Permanent International Meteorological Committee at their meeting at Utrecht in 1874.

It should be remembered that the permanent register is to be filed in the Office for future use not merely by the staff of the Office but by Meteorologists generally. Hence it is requested that the particulars of the position of the station, the heights of the instruments above Mean Sea Level, &c., be entered on each sheet even though the information may have been previously sent to the Office. The headings of most of the columns are self-explanatory. Should any alteration be necessary in any heading in order to describe more accurately the observations entered under it, the change should be made on *each form*. In copying from the rough book care should be taken to enter corresponding figures vertically under each other so that the columns may be added easily. Queries appended in the rough book to doubtful readings should be copied on to the permanent register.

The form hitherto in use at the Meteorological Office (No. 19 or 319 or 347) makes provision for the entry of observations at 9 a.m. and 9 p.m. In view of the importance of observations in the early afternoon in connexion with the diurnal variation of humidity and other elements, a new form (No. 355) has recently been prepared which makes provision for the entry of three observations each day. In this new form the order of the columns has been brought into harmony with that adopted in the scheme for publication prepared by the International Meteorological Committee. The specimen form shown in Appendix I., pp. 101–104 is a copy of one of these new forms.

The following additional notes and explanations will be found useful :—

Depression of Wet Bulb (columns 18–20). This quantity is the difference between the readings of the dry and wet bulb thermometers.

Clouds (columns 33–38). Should two or more forms of cloud be observed simultaneously they may be entered in the columns headed "Form," vertically under each other. For greater clearness a line should be drawn between the different entries thus $\frac{Ci_2}{st_3}$. Suffixes

may be used to indicate the amounts of each form visible, the amounts being estimated as described on p. 43.

The observer should confine himself in all cases strictly to what he sees and hence the sum of these suffixes should never exceed the figure given for the total amount of cloud. Thus, if the sky appears to be completely covered by a cirro-stratus film and some lower cloud, say cumulus estimated at amount three, be simultaneously observed, the entry should read $\frac{\text{Ci-st}_7}{\text{Cu}_3}$ and not $\frac{\text{Ci-st}_{10}}{\text{Cu}_3}$. The figure in the column headed "amount of cloud" should be 10.

At stations where the direction of all cloud forms is observed the results may be noted in this column thus $\frac{\text{W.}}{\text{S.W.}}$ This entry taken in conjunction with the one given above in the cloud-form column would mean that the cirrus cloud, which covered two tenths of the sky, was moving from the West, and that the stratus, covering three tenths of the sky, moved from S.W. If this method of notation be adopted care must be taken to avoid all chance of ambiguity. Thus in the above case, if the direction of the cirrus cloud had not been observed the correct entry would be $\frac{?}{\text{S.W.}}$; if the rate of motion had been found to be too slow to admit of a definite direction being made out, the entry should read $\frac{0}{\text{S.W.}}$. Again, if both cloud forms had been moving from S.W., the correct entry would be $\frac{\text{S.W.}}{\text{S.W.}}$.

Weather (columns 39–44). The Beaufort notation is to be used in filling in the columns headed "weather." In the columns headed "during interval ending I, II, III," a comma is used to separate phenomena which occurred one after another, thus o, r indicates dull at first, subsequently becoming rainy, while o r means dull and rainy throughout the period since the last observation.

Rainfall (column 45). The rainfall is measured at 9 a.m. The amount should invariably be entered to the day preceding that on which the measurement is made even on occasions when the observer knows that the rain fell during the early hours of the morning. A note to that effect may be made in the remarks column.

Extremes of Temperature (columns 16 and 17). Where possible these readings should be taken at 9 p.m. and entered to the day on which they are taken. If the readings are taken at 9 a.m., the maximum should invariably be thrown back to the previous day, and the minimum entered to the day of observation.

The occurrence of the extremes at unusual hours, *e.g.* min. during the day, or max. during the night may be noted in the "remarks" column.

Remarks.—The remarks column should be used to give a rather fuller description of the weather experienced between the hours of observations than is possible within the narrow limits of columns 42 to 44. To economise space the international symbols given on p. 51 should be used in filling it in. These symbols also indicate the character of the phenomena to which special attention should be directed. It is important to give as accurately as circumstances allow, the time and duration of the phenomena observed. In specifying hours of the day, the letter m, of the combinations a.m., p.m., is frequently omitted. A more satisfactory nomenclature is that of numbering the hours consecutively from 1 to 24. The following scheme of abbreviations has been accepted internationally for

specifying approximately the time on occasions when it is not possible to mention a particular hour :—

a.=the interval between the first and second hour of observing, *i.e.*, 9 a.m. to 3 p.m.

p.=the interval between the second and third hour of observing, *i.e.*, 3 p.m. to 9 p.m.

n. (night)=the interval between the third and first hour of observing, *i.e.*, 9 p.m. to 9 a.m.

The following specimen entries show what is desired :—● 10 h.–17 h.; ●^{2} at 16 h. ; K 16 h. 55 m. p. ; ▲^{2} 9h. 45 m. ; ≡^{2} till 11 h., cleared at 13 h. ; ⸙ all day, extreme force 10, from 18 h.–20 h. ; frequent sleet showers a. ; ⊕ 14 h. ; bright a., dull p.

The " Weather Diary " is a more detailed description of the course of the weather and the appearance of the sky each day than is usually given in the Remarks Column. Frequently questions arise which cannot be answered by consulting the observations at fixed hours, and it would facilitate considerably inquiries into the progress of exceptional weather to know exactly what was the course of events at all climatological stations. The character of the diary must depend to some extent on the opportunities and inclination of the observer. The following is an example of what may be done by an observer whose opportunities are limited by indoor occupation :—

December 7th, 1911. The early morning 7.30 a.m. was dark, wet, and blustering with continuous but not heavy rain. During the forenoon it cleared considerably but at 12.50 p.m. very dark clouds came over and the wind, which had been S.W., gradually changed to about W.N.W., and the air became cooler. The intense darkness cleared away in about 20 minutes, but the day remained gloomy and showery until sunset, after which the sky cleared.

The following is a fuller example :—

May 25th, 1904. Early morning overcast with thick fog. At 6 a.m. the sun broke through for a short time, fog thickening again, especially to westward ; after 7.30 a.m. the sun again broke through ; patches of blue sky increasing and frequent sunshine. The air is calm and warm. The fog appears to be turning into true cumulus cloud, especially in the west. It looks as though the day would not prove really fine. Right ; towards 10.30 a.m. it suddenly became so dark that it was difficult to read. A very black squall cloud covered the greater part of the sky. Immediately afterwards a gale from the westward sprang up, and rain fell in torrents. The squall cloud passed away but rain continued to fall. After 2.30 p.m. the sky cleared, and only a band of cirrus remained. The sun shone continuously, but the gale continued unabated till 6 p.m., and even then did not drop entirely. It has become cooler. After sunset clouds collected in the west, and continued to increase. At 9 p.m. the gale commenced afresh but subsequently the wind moderated, at times to a light breeze.

Summaries.—The column headed "symbols" is intended to simplify the computation of the summaries at the foot of the form. In it the symbols for all phenomena occurring on each day should be entered. The symbol for rainfall need not be entered, as the number of days of precipitation is easily found from the number of entries in the "rainfall" column which exceed ·005 inch.

The following definitions and conventions are adopted in preparing the summaries.

Days of precipitation.—The common practice of British Meteorologists has been to take ·01 inch (·005 inch in those cases where the rainfall was observed to thousandths of an inch) as the minimum for a "day of precipitation" (Rainday).

Days of snow.—In counting days of snow, the practice in this country has been to take no account of the amount which falls. Every day on which snow is observed, even though it is so small in quantity, as to yield no measurable amount in the rain gauge, is to be counted as a day of snow.

Days of hail.—The same practice should be followed in counting days of hail.

Days of thunderstorm.—In counting days of thunderstorm those days are to be included on which thunder is heard even though no lightning is seen; those on which lightning is seen but no thunder heard are not to be counted.

Days of clear sky.—The days of clear sky are those days when the mean of the amounts of cloud (scale 0–10) as observed at the hours fixed for observation is *less* than 2.

Days of overcast sky.—Similarly the days of overcast sky are those days when the mean of the amounts of cloud as observed at the hours fixed for observation is *greater* than 8.

Days of fog.—Only those days should be counted on which moderate or thick fog occurs, and on which the fog entirely surrounds the observer (*see* pp. 53, 54). Vis less than F.

Days of ground frost.—In order to summarise the readings of grass minimum thermometers, a day of ground frost is taken as a day on which the temperature on the grass falls to 30·4° or below this limit (*see* p. 31).

Days of gale.—Days of gale are those on which force 8 on the Beaufort scale or upwards was recorded at any time during the day.

It should be observed that while the period covered by a day of precipitation is the 24 hours ending at 9 a.m. on the subsequent day, the days of snow, hail, thunderstorm, and gale are the civil days ending at midnight.

Wind summaries.—The wind summaries show the number of times that the wind was reported under each of the 8 points N., N.E., E., S.E., S., S.W., W., N.W., and calm; directions such as S. by E., S.E. by E., &c., should, when noted, be taken as S., S.E., &c.; entries under the intermediate points, as N.N.E., should be alternately thrown forward to N.E. and backward to N. Thus if there are 2 entries N.N.E., the 1st would be entered to N.E., the second to N., while if there are 3 entries N.N.E. during the month the first will be entered to N.E., the 2nd to N., the 3rd to N.E.; hence the rule "if the number of entries for an intermediate point is even, half the number should be entered to each of the neighbouring principal points: if the number is odd, the whole number just less than half should be entered to the preceding principal point while the greater should be entered to the following point, the points being taken in the order N., N.N.E., N.E., E.N.E. etc."

The number of observations at 9 a.m. and 9 p.m. of moderate or strong wind (forces 4–7) is also stated.

It is requested that the form be filled in and sent to the Meteorological Office, South Kensington, London, S.W., or 122, George Street, Edinburgh, as the case may be, immediately after the end of the month. Observers will find it useful to keep the monthly sheet made up day by day.

PART II.

SELF-RECORDING INSTRUMENTS.

Instruments have been constructed to give continuous records of the majority of meteorological elements. In most of these instruments the motion of the working parts is magnified by a system of multiplying levers to the end of which is attached a pen, which records on a chart fixed on a revolving drum driven by clockwork. A good self-recording instrument should afford the means of determining, either directly or indirectly, the absolute value of the element recorded for any instant. As a rule this end can only be attained by using the continuous record to interpolate between the values given by eye observations at fixed intervals taken with standard instruments.

General Precautions.

Certain precautions and considerations which apply equally to all forms of recording instruments will now be discussed.

Dating of Charts.

(i.) The date (time, day, month and YEAR) of commencement and end of the record should be entered on each chart either before it is fixed on the instrument or immediately after it is taken off. The place at which the record is taken, and, if a number of instruments of the same kind are kept, the number of the instrument used should be entered on the chart. Should a record be missed in consequence of an accident (pen not marking, &c.), the chart should be filed with the successful records, and not be destroyed or used again. When recording rainfall or sunshine it will frequently happen that the chart, when taken out of the apparatus, is blank. In such cases it should always be dated and filed with the remaining records.

Friction.

Friction between the working parts of the apparatus must be avoided as far as possible. The bearings should be cleaned occasionally and oiled with a good clock oil, care being taken to remove excess of oil.

The most serious friction generally occurs between the pen and the paper on which it writes. The pen should be well washed from time to time in water or methylated spirit.

A thin clear trace should be aimed at, for if the trace be thick and blurred many of the smaller variations such as those shown on Saturday, November 17th, 1906, on the barogram reproduced in fig. 22, p. 72, which are most interesting meteorologically, become obliterated.

The point of the pen should be fine so as to give a narrow trace, but it must not be so fine as to scratch or stick to the paper. A new pen may frequently be improved by drawing the point once or twice along an oil-stone, but any trace of oil should afterwards be carefully removed.

Excess of ink should be avoided. Special care must be taken not to let the ink come in contact with the metal style which carries the pen, as this will cause the pen to adhere firmly to the style so that it cannot be removed and cleaned. The ink also causes the aluminium to become brittle and break. Should the style be accidentally inked, it should be immediately washed and slightly oiled.

The pressure of the pen on the paper should be reduced to the minimum consistent with a continuous trace for which simple contact with the paper will suffice. In instruments in which the elasticity of the style is made use of to keep the pen in contact with the paper the pressure should be adjusted by means of the milled head (B. fig. 21, p. 71), near the base of the style, so that the pen falls away from the paper when the instrument is tilted slightly.

Selection of Charts.

In many instruments the recording pen is fixed to a lever which is pivoted at one end, so that the pen moves along an arc of a a circle. The ordinates on the charts supplied for such instruments are, therefore, also arcs of circles, and it is essential that the radius of the arcs on the charts should be equal to the length of the pen arm, and that the centres of these arcs should be at the same level as the pivot on which the pen arm turns. In other words, the curve traced by the pen when the clock drum is at rest should coincide with the arcs on the charts. It is for the instrument maker rather than the observer to attend to these points; in most instruments no provision for adjustment is made. As the instruments of different firms, or even different patterns by the same firm, differ in dimensions, even though the size of the drum be the same, it is necessary to make sure that the charts are suitable for the particular instrument in use. When ordering a new supply of charts the maker's name and, whenever it is given, the number of the chart should always be quoted, especially if the order be given through a local agent. The use of charts with arcs of wrong radius will throw the time scale very considerably wrong, even though the range may appear to be correct. The width of the lower margin of the chart is also of importance. If it be too narrow or too wide the centre of the arcs on the charts will not be at the same level as the pivot on which the pen arm turns.

If the observer has any doubt as to the suitability of a chart for his particular instrument he may test it by moving the pen across it from its highest to its lowest position, and observing whether the trace is everywhere coincident with, or parallel to, the arcs engraved on the chart.

In order not to strain any part of the apparatus, the pen arm should be disconnected from the receiving apparatus before this is done, by removing one of the pins at some part in the system of levers by which the motion of the receiving apparatus is communicated to the pen.

The attention of the observer is once more directed to the fact that ink, if allowed to come in contact with the style which carries the pen will corrode it, with the result that the style breaks. A new style is then required as the use of a pen arm which is too short renders both time scale and range inaccurate.

Fixing the Charts on the Drum.

The chart is placed round the drum containing the clock where it is held in position by a spring. When fixing on the drum, care must be taken that the horizontal lines printed on the chart are parallel to the flange at the base of the drum. If the chart is carefully cut so that its lower edge is parallel to the horizontal lines, this will be the case when the edge of the chart is in contact with the flange all round the drum.

If the charts are not accurately cut, allowance should be made for the fact by eye. This may be done by seeing that the horizontal lines are continuous where the two ends of the chart overlap. In all Office charts the central horizontal lines are produced to the edge of the paper in order that this may be secured. Another method of overcoming the difficulty is to have a second and fixed pen attached to the instrument which will mark a horizontal base line on the chart. All measurements are then referred to this base line.

Time Scale.

A more serious difficulty is afforded by the checking of the time scale. The back-lash between the clock and the spindle on which it turns, renders accurate setting of the time scale a matter of considerable difficulty and in addition to this, errors in the clock-rate or in the ruling of the charts and also the effects of stretching due to changes in humidity may introduce considerable uncertainty. The result is that many records, on which much time and money have been spent, are all but useless for scientific purposes. The difficulty may be avoided to a great extent by making time-marks at known instants by slightly moving the recording pen. Office barographs are now fitted with a "time marker" (A. fig. 21, p. 71) for slightly depressing the pen arm and so causing it to record a time mark; when this is not provided a mark may be made by gently tapping the instrument but, if that be done, care must be taken not to shake the drum on its spindle or to otherwise interfere with the record. In the case of thermographs and hygrographs there is no necessity for a special lever, as the pen arm can be easily moved from the outside. If the instrument is as free from friction as it ought to be, no discontinuity need be caused in the trace by the time marks. The absence of discontinuity in the trace furnishes good evidence that the instrument is working well.

If possible, time marks should be made punctually to the minute at a fixed hour every day, preferably at the time when the standard instruments are read. If this is inconvenient, arbitrary times may be selected and carefully noted correctly to the nearest minute. These times should be entered on the records before they are filed. Time marks should not be made until some time after changing the record sheets in order to allow the clock to take up the back-lash. The effect of back-lash may be reduced to a minimum if the cylinder be turned on its spindle so as to bring the pen *back* to the required time from a point in advance of its proper setting. The rate of revolution of the cylinder can be adjusted to agree approximately with the time scale of the charts by means of an ordinary clock regulator.

Interpolation.

The observer should satisfy himself that his instrument is working properly by frequently comparing its indications with the readings

of standard instruments.* In the ideal case the difference between the reading of the standard and the value deduced from the curve is zero. In practice small discrepancies always occur.

We may distinguish three cases :

(1.) When the difference is constant at all points of the scale, an error in setting is indicated.

(2.) When the difference is zero at one point on the scale but increases proportionately on either side of this point, we may infer that the range of the instrument does not correspond to that marked on the scale.

(3.) Irregular variations are due mainly to friction in the working parts ; lagging, structural defects, etc., produce similar effects. In practice all these cases may be combined.

If cases (1) and (2) are alone in question we may obtain accurate values for any intermediate epoch as follows :—

Let C_1 and C_2 be the curve readings corresponding to the fixed hour readings S_1 and S_2, taken on the standard instruments before and after the epoch in question.

Let c be the change shown by the curve between the fixed hour corresponding to S_1 and the desired epoch, and let s be the true change in the same interval,

$$\text{then } \frac{s}{S_1 - S_2} = \frac{c}{C_1 - C_2}$$

$$\text{or } s = c \times \frac{S_1 - S_2}{C_1 - C_2}$$

The value for s so found, when added or subtracted from S_1, gives the true value required.

The irregular variations of the difference described under case 3, cannot be satisfactorily allowed for ; they must be reduced to a minimum by careful attention to the instrument.

* A satisfactory, though somewhat laborious, method of doing this is to tabulate the readings of the curve for 9 a.m. and 9 p.m., and compare them with the readings of the standard instruments. An incidental advantage of this procedure is that it helps to identify errors in reading the standards. (·05 or ·10 inch in the case of the barometer, 5° or 10° in the case of the thermometer.)

The Barograph.

The motion in most barographs is furnished by a set of aneroid boxes. (Fig. 21.) The instruments used at official stations of the Meteorological Office are of two sizes. We proceed to specify the dimensions of those parts of the apparatus which affect the size and ruling of the charts. These are (1) the length of the arm carrying the pen, measured from pivot to pen point; (2) the height of the pivot of the pen-arm above the flange on the drum, against which the chart rests; (3) the magnification of the pen motion, *i.e.*, the vertical distance on the chart corresponding with a change of pressure of one inch of mercury. The latter depends on the number and size of the aneroid boxes and on the arrangement of the levers. The horizontal distance on the Meteorological Office charts corresponding with an interval of 12 hours is also given.

These dimensions are as follows :—

—	Large Instrument.	Small Instrument.
Length of pen-arm	10·24 ins.	7·29 ins.
Height of pivot above flange	3·11 ins.	1·57 ins.
Magnification of scale	2	1
12 hours on time scale	1·07 inch.	0·78 inch.

The diameters of the drums are respectively 4·97 inches and 3·65 inches.

The scale usually reads from 28 to 31 inches. This range is sufficiently great to include all pressure values usually met with in the British Isles, if the instrument be set to agree with the reading of a standard mercury barometer reduced to 32° and to mean sea level. Both these limits have, however, been exceeded.

Different devices for setting the position of the pen on the chart are adopted in different instruments. In many the adjustment is made from below by turning the screw which will be found under the aneroid boxes, with the clock key. If the pen is observed to be very near the top or bottom of the chart the danger of the loss of a particularly interesting record may be averted by using the adjustment to bring the pen nearer the centre of the chart, but if this be done the instrument should be re-set by comparison with a standard mercury barometer as soon as the pressure resumes a more usual value.

Barographs in which the motion of the pen is furnished by a set of aneroid boxes are subject to changes of zero. When absolute pressure values are required their use must accordingly be confined to interpolating between the readings of standard mercury barometers. If the instrument is in good order, and if the pressure is changing slowly, the height of the barometer at any desired epoch may be determined as follows:—Read off from the curve the amount the barometer has risen or fallen since the previous reading of the mercury barometer was taken, the time-scale being checked and, if necessary, corrected by means of the time marks (*see* p. 68), and add or subtract this amount from the corrected reading of the mercury barometer. The result should be checked by working backwards

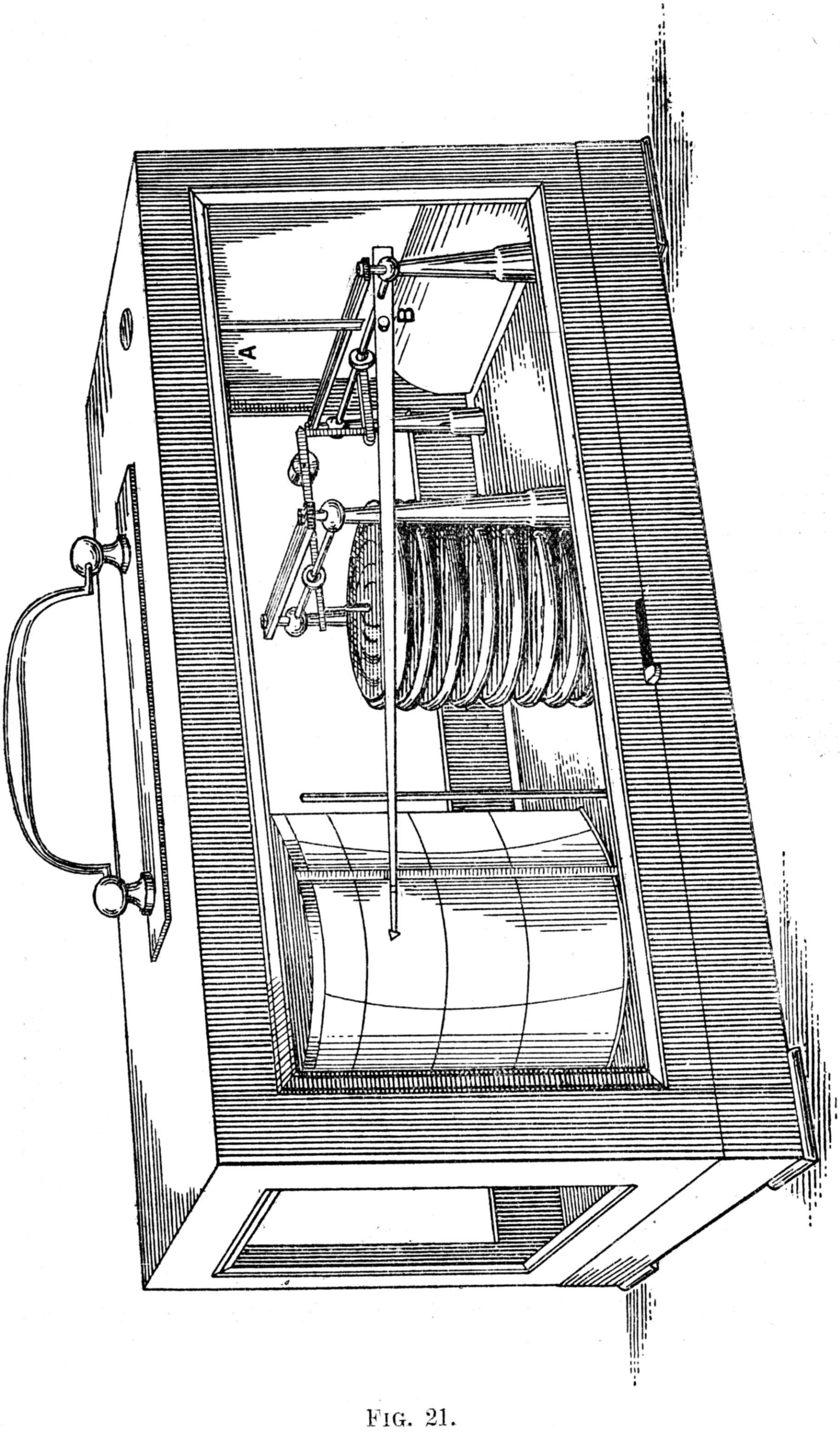


Fig. 21.

from the next following reading of the standard. As a rule the difference between the two values so deduced will be slight. Suppose for example we desire to find the pressure at sea level in

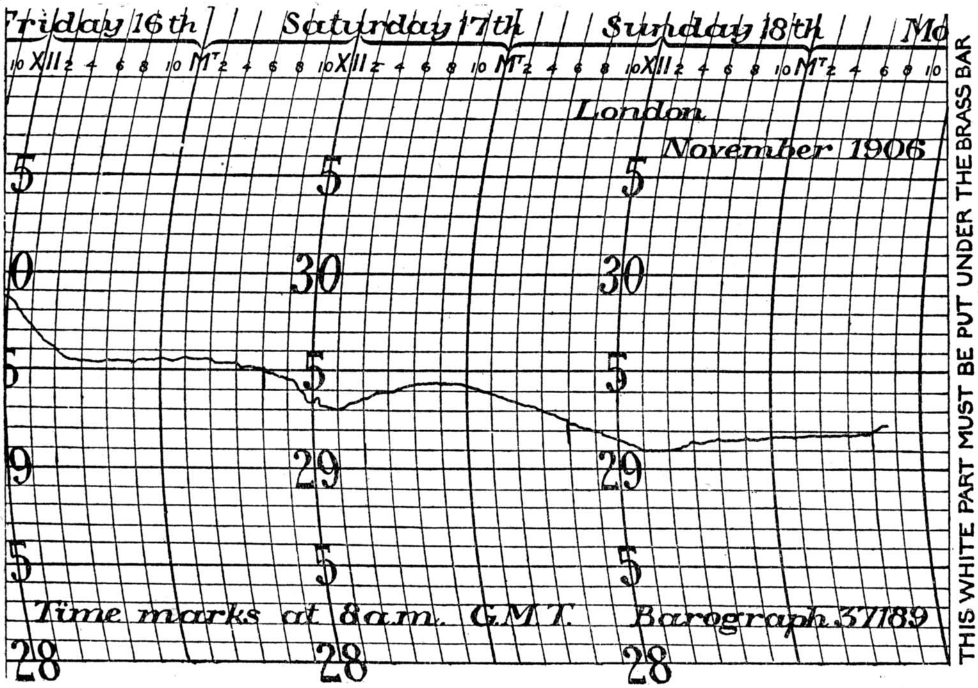


FIG. 22.

London at noon on Saturday, 17th November, 1906, from the barogram reproduced in Fig. 22. The time marks were made at 8h. 0m. a.m. They fall as nearly as may be on the hour lines, so that the time scale may be taken as correct. The curve shows that the pressure decreased by 0·17 inch between 8 a.m. and noon. From the Daily Weather Report we find that the reading of the mercury barometer at 8 a.m. was 29·47 inches. Hence the pressure at noon was 29·30 inches. To confirm this value we may work back from the subsequent reading of the mercury barometer at 6 p.m. This is given in the Daily Weather Report as 29·37 inches. The curve shows a total increase of pressure between noon and 6 p.m. of ·07 inch. The value at noon was thus 29·30 inches, which agrees with that found above. If the pressure is changing rapidly more elaborate methods of interpolation must be employed as described on p. 69.

Exposure.—A position should be selected where the instrument will be protected from shaking and from sudden changes of temperature.

An excellent cushion for a barograph may be formed with two pieces of rubber tubing.

The Thermograph.

In most thermographs the thermometer consists of a slightly curved metal tube filled with spirit (Bourdon tube) the curvature of which changes with change of temperature, or of a metal spiral which coils or uncoils as the temperature changes. One end of the thermometer is fixed rigidly to the instrument while the other is connected either directly or by levers to the recording pen.

From the nature of the case thermographs for meteorological use must be exposed out of doors, preferably in a Stevenson screen, and hence it is necessary to clean and oil their bearings much more frequently than is the case with barographs, especially in towns where dirt accumulates rapidly.

In all instruments there is a device for altering the position of the pen on the chart and so setting the instrument for different climates or different seasons. Two kinds of chart are used in the British Isles; the *Winter Chart* has a range from—10° F. to 65° F., the *Summer Chart* from 30° F. to 105° F. The proper date for changing from one set of charts to another varies with the locality. For London the change should be made about the middle of April and the middle of October. The setting may be accomplished by using the mechanism provided in the thermograph to adjust the indication of the new chart to agree with the reading of a mercury thermometer placed beside it in the screen. The change should only be made at times when the temperature is constant or changing slowly, and only when the pen is near the middle of its range. As the tube or coil is in thermal contact with the body of the instrument (which takes an appreciable time to alter in temperature) it is apt to be somewhat sluggish when the changes of temperature are rapid. In most instruments there is no device for altering the range, *i.e.* the amount of motion of the pen corresponding with a change of temperature of one degree.

The readings of the thermograph require frequent checking by comparison with standard instruments. A convenient plan is to place a standard maximum and a standard minimum thermometer in the screen with the instrument and to read and set these at regular hours, time marks being made at the hours of reading. It should be borne in mind that in cases where the trace shows that the extreme was of very short duration the sluggishness referred to above may cause a considerable difference between the reading of the standard and that of the recorder. It is not desirable to crowd a wet and dry bulb thermometer, a maximum and minimum thermometer, a thermograph and perhaps also a hygrograph into a Stevenson screen of ordinary dimensions. Such a course interferes with the adequate ventilation of the instruments. We may either use separate screens for the various instruments, or construct a special screen similar to that described in Appendix V. but of enlarged dimensions. If the length of the screen be increased from 18 inches to 36 inches the other dimensions being as specified in Appendix V. the four thermometers can be set up in the usual way in the middle part of the screen with the thermograph and hygrograph on either side. A clear space of at least three inches should be left between the various instruments or between the instruments and the louvres of the screen.

The Hair Hygrograph.

These instruments depend in their action on the fact that the length of a human hair, which has been freed from fat by boiling in caustic soda or potash, varies with the relative humidity, but not with other meteorological elements. It increases in length as the humidity increases and *vice-versa*. In practice, a small bundle of hair is used for actuating the lever bearing the recording pen.

As is the case with the thermograph, the instrument must be exposed out of doors (in a Stevenson screen, *see* p. 73), so that frequent cleaning and oiling of the bearings are necessary.

Unfortunately, the properties of hair are subject to gradual changes, so that the reading is not always the same under the same conditions of humidity. Frequent setting is therefore necessary. The setting is accomplished by turning a screw which varies the distance between the jaws which hold the hair. The instrument should read 100 per cent. of relative humidity when in a saturated atmosphere. The latter may be obtained by wrapping the instrument in wet towels, so that only the scale is visible, and leaving it for about 1 hour. The final adjustment should of course be made while in the saturated atmosphere.

A simpler method of setting, which has been found to give satisfactory results, is to wet the hairs with water by means of a camel-hair brush. When they are thoroughly wet and the reading has become constant, the instrument should be set to read 95 per cent.

A little experience with a hygrograph will show that the humidity of the air frequently varies very rapidly, so that small errors in the time scale may become very serious. Accurate time marks (*see* p. 68) are therefore very important.

For the same reason the comparison of the values of the humidity obtained from the curves with simultaneous values calculated from readings of dry and wet bulb thermometers is difficult. Sluggishness in either instrument may give rise to discrepancies. Another cause of difference lies in the fact that the reading of a wet bulb depends to some extent on the rate at which air is flowing past it. A single comparison is thus of little value, but on a long series of observations the mean difference between the readings should be small.

Self-recording Rain Gauges.

Autographic rain gauges in common use are of three types :—

(1.) Tilting bucket gauges.

(2.) Float gauges.

(3.) Balance gauges.

Whatever form of autographic gauge is adopted, its readings should always be checked by placing near it under conditions of similar exposure an ordinary gauge which is read once a day. The conditions which the exposure, etc., should satisfy have been fully described on pp. 10 and 35.

Float Gauges.

In these instruments the rain-water flows from the collecting funnel into a cylindrical vessel containing water in which there is a float. As more water collects the float rises in the containing cylinder, the rate of rise being proportional to the rate of rainfall. By making the area of the collecting funnel large compared with that of the receiving cylinder a very open scale can be obtained. The motion of the float is recorded by attaching to it an arm bearing a pen which writes on a revolving drum. When the float reaches the top of the cylinder a siphon is automatically thrown into action, the water is siphoned off and the pen returns to the base line. The connection between the siphon and the receiving cylinder is then broken until sufficient rain-water has been collected to fill the apparatus again.

A more recent form of instrument dispenses with the automatic siphon. The receiver is of sufficient capacity to hold a rainfall of six inches and the float rises continuously through a height corresponding with this amount of rain. When the pen reaches the top of the drum, which will generally be the case after half an inch of rain has fallen, an arrangement comes into play automatically whereby the pen arm falls back to zero. A hand siphon serves to empty the gauge when necessary.

When working with float pattern gauges attention should be paid to the following points :—

(1.) Sticking or jamming of the working parts must be guarded against by cleaning the instrument from time to time. Want of level is also frequently the cause of sticking.

(2.) The amount of water left in the cylinder after a discharge must be sufficient to lift the float off the base of the cylinder. If this is not the case a small amount of water will have to collect before the float begins to rise.

(3.) After each half inch of rain has fallen the pen should return to the zero of the scale.

(4.) The discharging siphon or the catch that allows the pen to return to zero, must be regulated to come into action as the pen reaches the top of the chart.

Note.—The siphon of a self-recording gauge is liable to give trouble in various ways. It may not be large enough to carry away the water properly in a heavy storm, and it may get blocked by insects or leaves. The gauge therefore requires careful attention.

Tilting Bucket Gauges.

In these instruments the rain water passes from the collecting funnel to the "tilting bucket" in which it is measured. The latter consists of an elongated flat bottomed trough with open ends which is divided into two parts by a central transverse partition and pivoted about its central point like the beam of a balance. When the left-hand end of the trough is depressed the rain-water is collected on the right-hand side of the partition. The balance is so adjusted that the weight of the water collected causes the bucket to tilt over as soon as it reaches the amount of ·01 inch, or in more sensitive instruments, ·005 inch. This tilting causes the water to flow from the bucket into a small receiving funnel whence it passes to a collecting vessel or runs away. If rain continues to fall it is now received in the trough on the left-hand side of the partition until another ·01 inch has fallen, when a second tilt will occur.

The instrument is made autographic by arranging for each tilt of the bucket to raise an arm bearing a pen which records on a revolving drum, through a short step. The height through which the pen is raised is thus proportional to the amount of rain which has fallen. A simple arrangement allows the pen to fall back to the zero of the scale when it reaches the top of the drum. If desired the tilting bucket and the reading apparatus may be put in separate cases and connected electrically. With this form of apparatus the gauge may be suitably exposed, while the recorder is placed within doors in any place that happens to be convenient. It will be perceived that the record is not continuous; each step on the chart corresponds with a fall of ·01 inch during the interval between it and the previous step.

This type of gauge gives fair results for heavy falls, but is useless for measuring the duration of gentle rain.

Balance Gauge.

A third pattern of autographic rain gauge depends on the principle of maintaining the equilibrium of the receiver by a curved lever bearing a weight. As water accumulates in the receiver it sinks at a rate proportional to the rate of rainfall, and when full it empties automatically, either by the inversion of the vessel or by the agency of a syphon.

With all these types of instruments the precautions detailed on pp. 66 to 69 must be observed. In some float and balance pattern gauges the motion of the pen is along a straight line, and hence the ordinates on the charts are also straight lines and no trouble can arise in consequence of their being drawn with a wrong radius. (*See* p. 67.)

It is desirable to test the instruments at regular intervals by pouring measured quantities of water through them and observing whether they are working satisfactorily. This test is specially necessary when no rain has fallen for some time.

Anemometers.

The question of exposure enters into all matters connected with the measurement of wind to a very large extent, so much so, that it may without exaggeration be said that the exposure is of more importance than the actual instrument. At many stations the orographical features are such that the provision of an anemometer is not to be recommended, unless it be intended to investigate such special points as the effect of the configuration of the land on the wind.

The site selected for the instrument should be such that it is not sheltered by trees or buildings, and it should be remembered that the eddies caused by such obstacles extend both vertically and horizontally to great distances. In a perfectly open and flat situation, a scaffolding some 30 feet in height affords an excellent exposure.

Anemometers may be divided into three main types :—

(1.) Robinson cup anemometers.
(2.) Pressure tube anemometers.
(3.) Pressure plate anemometers.

The Cup Anemometer.

The cup anemometer consists of four hemispherical cups attached to the ends of two crossed metal arms. The cross is pivoted at its central point, in such a way that it is free to rotate in a horizontal plane. The difference of pressure of the wind on the convex and concave surfaces of the cups, causes the cross to spin round.

The number of revolutions of the cups in a given time is proportional to the amount of wind which passes them. The ratio of the distance travelled by the wind to the distance travelled by the cups is known as the "factor" of the anemometer. The measurements of wind velocity with the Robinson anemometer have been subject for many years past to great uncertainty, in the absence of any agreement as to the appropriate factor for the reduction of the readings.

The cup anemometers belonging to the Meteorological Office are of two kinds :—

(1.) Robinson anemometer of standard pattern (9 in. cups and 2 ft. arms).

(2.) Robinson anemometer of smaller size (5 in. cups and 1 ft. arms).

The readings of the two instruments are brought into agreement within the limits of experimental accuracy by using, instead of factor 3, the factor 2·2 for the Robinson instrument of standard size and 2·8 for the smaller size. For instruments of other dimensions, other factors would be required. The use of the factor 3 has been discontinued in the publications of the Meteorological Office since January 1st, 1905.

The difference between the factor 3 and the factor 2·2 is so great that in supplying anemometric instruments of any kind, it is necessary to inquire what is the basis of graduation of the particular instrument supplied, in order that the distinction may be drawn between the nominal miles per hour of the standard Robinson with factor 3, and the statute miles which would be obtained from the same instrument with factor 2·2.

In some cases it is possible that the maker may supply sufficient information to identify the scale of the instrument, but if not the instrument should be compared at Kew with the standard there, before being used.

In the simplest form of Robinson anemometer, the total number of revolutions of the cups is recorded on a dial graduated to read in "miles of wind." The difference between consecutive readings gives the number of "miles of wind" which have passed the apparatus since last reading.

The more elaborate instruments are arranged to give a continuous record, on which the run of the cups during any desired interval can be read off, and hence the average velocity of the wind during that interval can be determined.

The vertical shaft which transmits the motion of the cups to the dial or to the recording apparatus should be of considerable length, so that a good exposure can be obtained for the former without placing the latter in an excessively inconvenient position. If the shaft is very short, the eddies set up by the presence of the recording apparatus may affect the cups appreciably.

The Pressure Tube Anemometer.

THE HEAD.

In the Dines Pressure Tube Anemometer the receiving apparatus consists of a comparatively light head, which is mounted on the top of a long pole, and connected with the recording apparatus by means of flexible tubing.

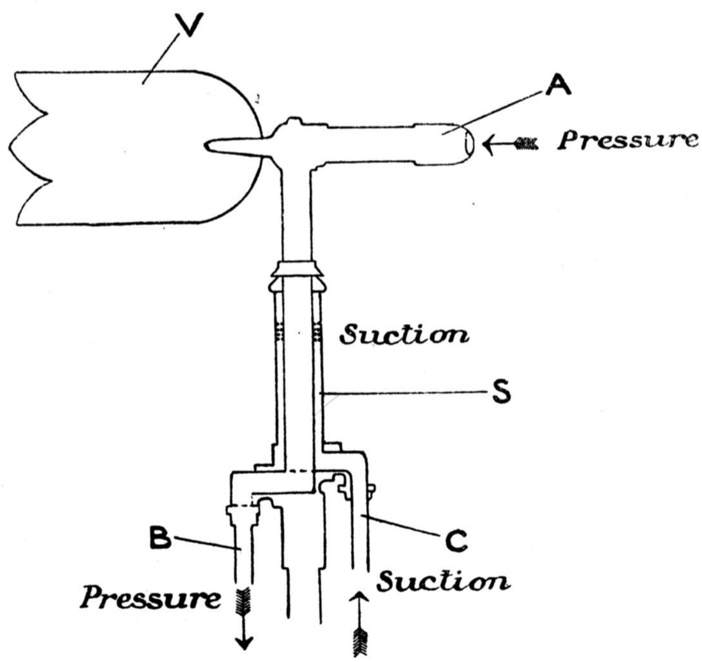


FIG. 23. HEAD OF PRESSURE TUBE ANEMOMETER.

The construction of the head will be understood from the diagram, Fig. 23. The upper part is free to rotate, and the vane V thus keeps the horizontal tube A facing the direction from which the wind is coming. The wind blowing into this open tube A produces an increase of pressure inside it, which is transmitted through the central tube of the head to the recording apparatus by means of flexible tubing attached to the tube B. The fixed part of the central tube is surrounded by an outer tube S in which there are four rows of perforations. Wind blowing past these produces a diminution of pressure in the annular space between the two tubes, and this is transmitted to the recorder by mean of a flexible pipe attached at C. The flexible pipes may be of considerable length, say 40 or 50 feet, so that the recorder can be placed a long way from the head.

When setting up the head care must be taken that the axis about which it rotates is vertical and that the flexible pipes have a fall throughout so as to prevent the lodgment of water. When once fixed the head requires little attention, beyond being occasionally cleaned. No oil or grease should be used.

Recording Apparatus.

When arranged for automatic recording, the pressure tube anemometer possesses the great advantage over the cup anemometer that it enables us to determine the changes in the wind velocity from moment to moment, and not merely the average velocity for a given interval.

The recorder (Fig. 24) consists of a float F, which is placed mouth downwards in a closed tank T partially filled with water. Tubes marked respectively S (suction) and P (pressure) lead into the air spaces above and below the float, and are connected with the two flexible tubes from the head. The connections are so arranged that the tube transmitting the increase of pressure communicates with the space below the float while that transmitting the decrease of pressure communicates with the space above it. The increase and decrease of pressure on the two sides of the float combine to raise the float, and a record of the motion of the latter is thus a record of the wind blowing past the head.

The arrangement for tracing the record is as follows :—To the top of the float is attached a vertical rod A which passes through what is practically an air-tight collar in the cover of the tank; this rod carries a pen which records on a drum D rotated by clockwork. To the rod is attached a guide B which moves in a vertical slot C, and prevents the float from rotating.

The shape of the inner surface E of the float is of great importance. It is so constructed that the displacement of the recording pen from the zero of the scale is proportional to the velocity of the wind at the head. The combination of the pressure and suction effects in the manner described increases the motion of the float, but its primary object is to eliminate the effects of changes in the pressure of the air in the room in which the recorder is placed.

When adjusting the apparatus it is necessary that the air pressure should be the same on both sides of the float. To effect this two three-way stop-cocks, G and H, are provided which enable us to

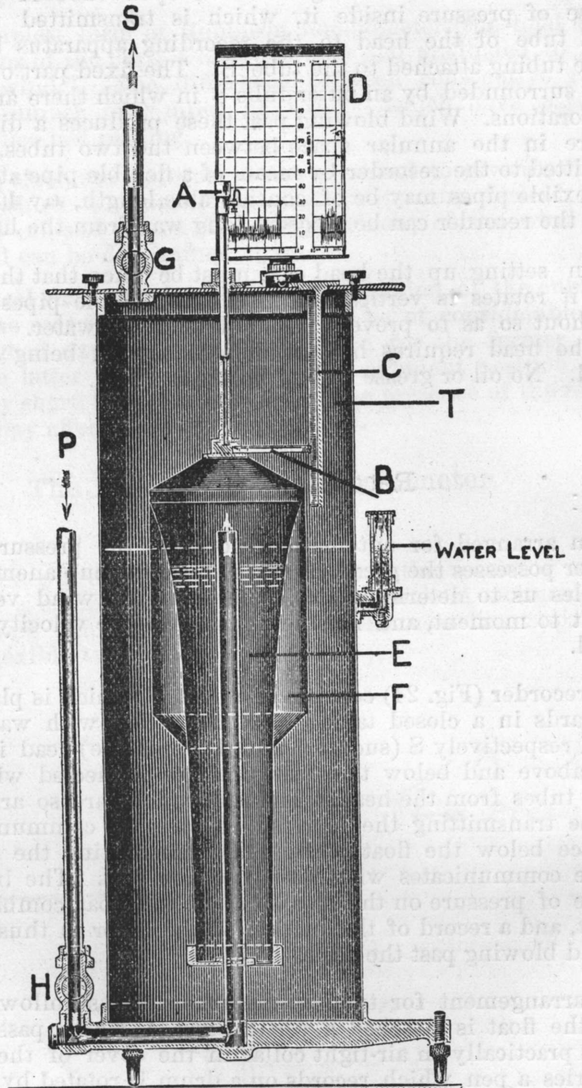


FIG. 24. DINES'S PRESSURE TUBE RECORDER.

close the tubes leading to the head, and to place the air spaces above and below the float in communication with the air of the room.

In the management of the instrument attention is directed to the following points :—

(1.) The instrument should be kept clean so as to admit of the free working of all its parts.

(2.) It must be kept level. To test the level remove the collar through which the pen rod passes, and note whether the latter passes

through the centre of the circular hole in the top of the recorder. If not, adjust by means of the levelling screws. Replace the pen carriage on the rod before making the adjustment. The screws should bear on a metal surface and not on wood.

(3.) The level of the water in the tank should be kept up to the fixed mark in the gauge which projects from the side of the apparatus.

(4.) When the pressure is identical on both sides of the float, the float should be quite free, *i.e.*, it should not be supported on the base of the tank. If it is, there will be a "dead" interval within which the upthrust on the float produced by wind is not sufficient to raise it.

The float is so constructed that it rests at a given level denoted by a mark on the stem.* If the adjustment is not perfect, it should be altered by adding or withdrawing shot from the cup which will be found on the pen carriage.

(5.) The position of the pen should correspond with the zero of the scale when the air pressure is the same on both sides of the float, *i.e.*, when both taps are turned so that communication with the head is shut off. A screw motion is provided for making this adjustment.

(6.) From time to time the pressure tap should be opened while the suction tap is closed and vice-versa to see if both pressure and suction are working.

Pressure tube recorders are primarily graduated upon an empirical basis by Mr. Dines's experiments,† but the indications of different instruments can be compared with a pressure gauge.

The comparison may be made as follows :—With a piece of india-rubber tubing make a U tube out of two pieces of glass tube about 1 foot long and $\frac{1}{2}$ inch in diameter. Half fill the U with water. To one arm of the U attach an india-rubber tube to which a T piece has been fixed. Disconnect the flexible tube which goes to the anemometer head from the pipe which leads into the space below the float, and connect the latter with one arm of the T by means of an india-rubber tube. Turn the other tap so as to close the tube leading to the head and put the air above the float into communication with the air of the room. To the open arm of the T attach a small piece of india-rubber tubing which can be closed at will with a pinchcock or stopper. The pressure of the air above the float is then the same as the pressure in the open branch of the U, and the pressure of the air imprisoned under the float is the same as the pressure in the closed branch of the U. Now raise the pressure in the enclosed air space by blowing down the T piece, and note the reading of the anemometer pen on the chart and the corresponding difference in level of the water in the two arms of the U. If the anemometer is in good order and properly adjusted, the relation between the reading on the chart, V, in miles per hour, and the difference in level, W, of the water in the two arms of the U, measured in inches, should be given by the relation ·01854 m

$$W = \cdot 00073_1 V^2.$$

The following table gives corresponding values of W and V calculated from this formula :—

V	10	20	30	40	50	60	70	80	90	100
W	·073	·292	·658	1·17	1·83	2·63	3·58	4·68	5·92	7·31

* In the earlier instruments, the zero position was that in which the float just rested in contact with the base of the water tank without exerting appreciable pressure on it.

† Quarterly Journal Royal Meteorological Society, Vol. xvi., p. 208, Vol. xviii., p. 165.

The graduations on the charts of the recorder are as a rule arranged to give both wind velocities in miles per hour and wind pressures in pounds per square foot. The relation between the two quantities is given by the formula

$$P = \cdot 003\ V^2,$$

where P is the wind pressure in pounds per square foot and V the wind velocity in statute miles per hour.

The corresponding formula in c.g.s. units is

$$p = 72\ v^2,$$

where p is the resultant force in kilodynes upon a disc of one square metre in area set across a current of air of standard density and v is the velocity in metres per second.

Instruments for Recording Wind Direction.

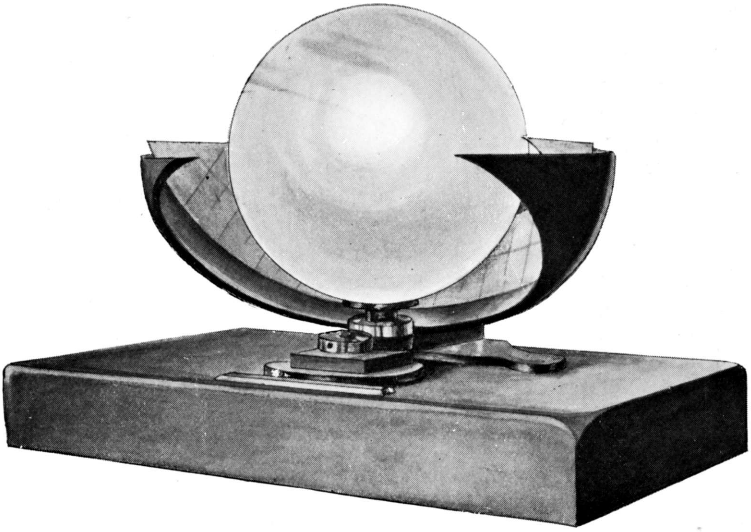
The more elaborate forms of anemometer record wind direction as well as wind velocity. With these instruments the orientation should be tested from time to time. In doing this two points must be attended to—

(1.) The direction recorded on the drum must coincide with that of the line of symmetry of the vane.

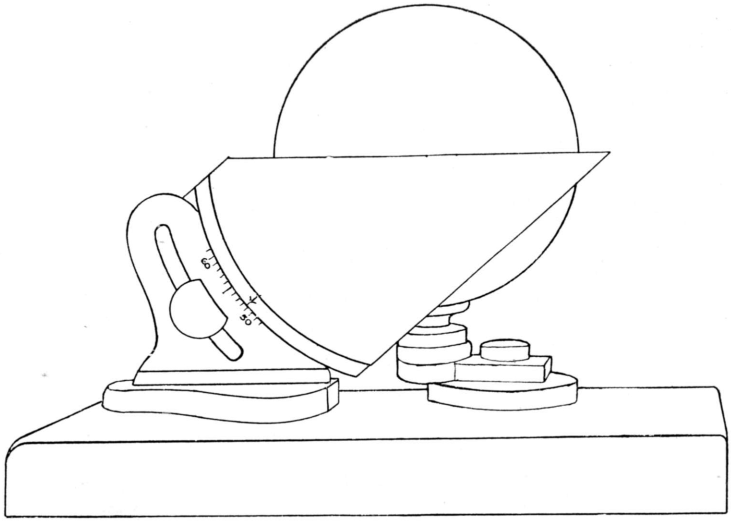
(2.) The vane must set itself along the wind direction. This may be tested by attaching a long streamer to the tube down which the central shaft passes and observing whether the wind extends the streamer parallel to the line of symmetry of the vane.

Pressure Tube Anemometer for Recording Direction and Velocity.

A modification of the "head" and connections of the pressure tube anemometer has recently been adopted by the Meteorological Office which enables the motion of the vane of the instrument to be transmitted through the supporting tube to the stand of the recording drum, vertically beneath. By an apparatus designed by Mr. W. H. Dines, F.R.S., the motion is recorded on the paper which takes the velocity-record. On the recording sheet the directions are set out between two horizontal lines, both of which are marked N., and which form the top and bottom lines of the direction-chart. The variation of the direction of the vane is transformed into motion up or down the sheet by means of a cam. Two pens are employed, one or other of which moves with the vane, even if the vane makes more than a complete revolution. The apparatus is described by Mr. J. S. Dines in the Fourth Report on Wind Structure (Technical Report of the Advisory Committee for Aeronautics for the year 1912–13). In working the instrument, it is important to see that the pens are so adjusted that one marks the top and the other the bottom of the direction-chart when the vane points due north, and that they are close together, but do not foul, as they pass one another in taking up those positions.



CAMPBELL–STOKES SUNSHINE RECORDER.



CAMPBELL–STOKES SUNSHINE RECORDER, SIDE VIEW, SHOWING THE ADJUSTMENT FOR LATITUDE.

The Campbell-Stokes Sunshine Recorder.

The sunshine recorder devised by Mr. Campbell of Islay and modified by Sir George Stokes consists essentially of two parts :—

(1.) A glass sphere which brings the sun's rays to a focus.

(2.) A metal bowl carrying cards to form a belt, approximately spherical, on which the sun burns a record.

Plate III. shows the recorder with the sphere in position.

The specification of the dimensions of the instruments used by the Meteorological Office is given below (p. 93).

Exposure.

The conditions which the exposure should satisfy have already been described on p. 11. We may briefly recapitulate them here. A perfectly free horizon is required between N.E. and S.E. on the East side, and between N.W. and S.W. on the West side, these being the approximate limits of the position of the rising and setting sun in our latitude. An obstruction to the south should not be higher than from one-eighth to one-third of its distance from the instrument, according to the latitude of the station. Obstruction to the northward between N.E. and N.W. is of no consequence. The support on which the instrument is placed should be perfectly rigid and be made of a material which is not liable to warp or to become otherwise deformed.

It is not in all cases possible to secure a site for the instrument where it will have an absolutely uninterrupted exposure. In such circumstances it is desirable to estimate how much of the "possible" sunshine may be cut off by the surrounding obstacles at different times of the year.

From the diagrams (Plate IIIa., p. 84) showing the altitude and azimuth of the sun, the duration of sunshine cut off by any obstacle can be found for any time of the year at any latitude between 50° and 60°. The different curves in each diagram refer to the dates shown below. For intermediate dates interpolate an imaginary curve for the corresponding noon-altitude. The latter is equal to the colatitude (90° − latitude) + the sun's declination. The declination at different dates can be found from Whitaker's Almanack. In order to estimate the amount of sunshine cut off by an obstacle, find the altitude and azimuth of its salient points when viewed from the sunshine recorder. Plot these on the diagram for the latitude nearest to that of the station and find the length of curve cut off by the object. Thus the house shown in the diagram cuts off on October 25th, or February 18th, 1 hour 40 min., 1 hour 50 min., 1 hour 55 min. for latitudes 50°, 55°, 60° N. respectively.

At the winter solstice it cuts off nearly an hour in lat. 50°, less than ½ an hour in lat. 55°, and nothing at all in lat. 60°.

Key to the different curves shown under each latitude :—

	Sun's Declination.	Northern Hemisphere.	Southern Hemisphere.
June 22nd, Solstice	23½° N.	A	E
April 21st, August 23rd	11¾° N.	B	D
March 21st, September 23rd, Equinoxes	0	C	C
February 18th, October 25th	11¾° S.	D	B
December 22nd, Solstice	23½° S.	E	A

The Adjustments of a Sunshine Recorder.

When setting up a sunshine recorder the following adjustments must be accurately made :—

(1). The centre of the glass sphere must coincide with the centre of the bowl.

(2). The plane cutting an equinoctial (straight) card mounted under the central flanges on the bowl along its central line must be inclined to the vertical at an angle equal to the latitude of the place.

(3). The instrument must be level as regards East and West, *i.e.*, the line joining the middle points of the six o'clock lines on the equinoctial card must be horizontal.

(4). The plane passing through the centre of the sphere and the "noon marks" on the bowl must be in the plane of the meridian.

The adjustment for concentricity is made by altering the position of the pedestal which supports the sphere. In the form of recorder now adopted by the Meteorological Office simple motions are provided whereby this can be done. In the older instruments the pedestal can be released for the purpose of adjustment by loosening a screw below the slate base. The hole in the slate through which the pedestal passes should be made rather large in order to allow of adjustment.

The modern instruments are also provided with an easy means of making the adjustment for latitude within certain limits. By loosening a screw at the back of the bowl, the latter can be slid through an arc of about 15°. If the arrow head on the bowl be set to the point on the graduated scale (Plate III.) corresponding with the latitude of the place it will be found that the instrument is in adjustment for latitude when its base is horizontal.

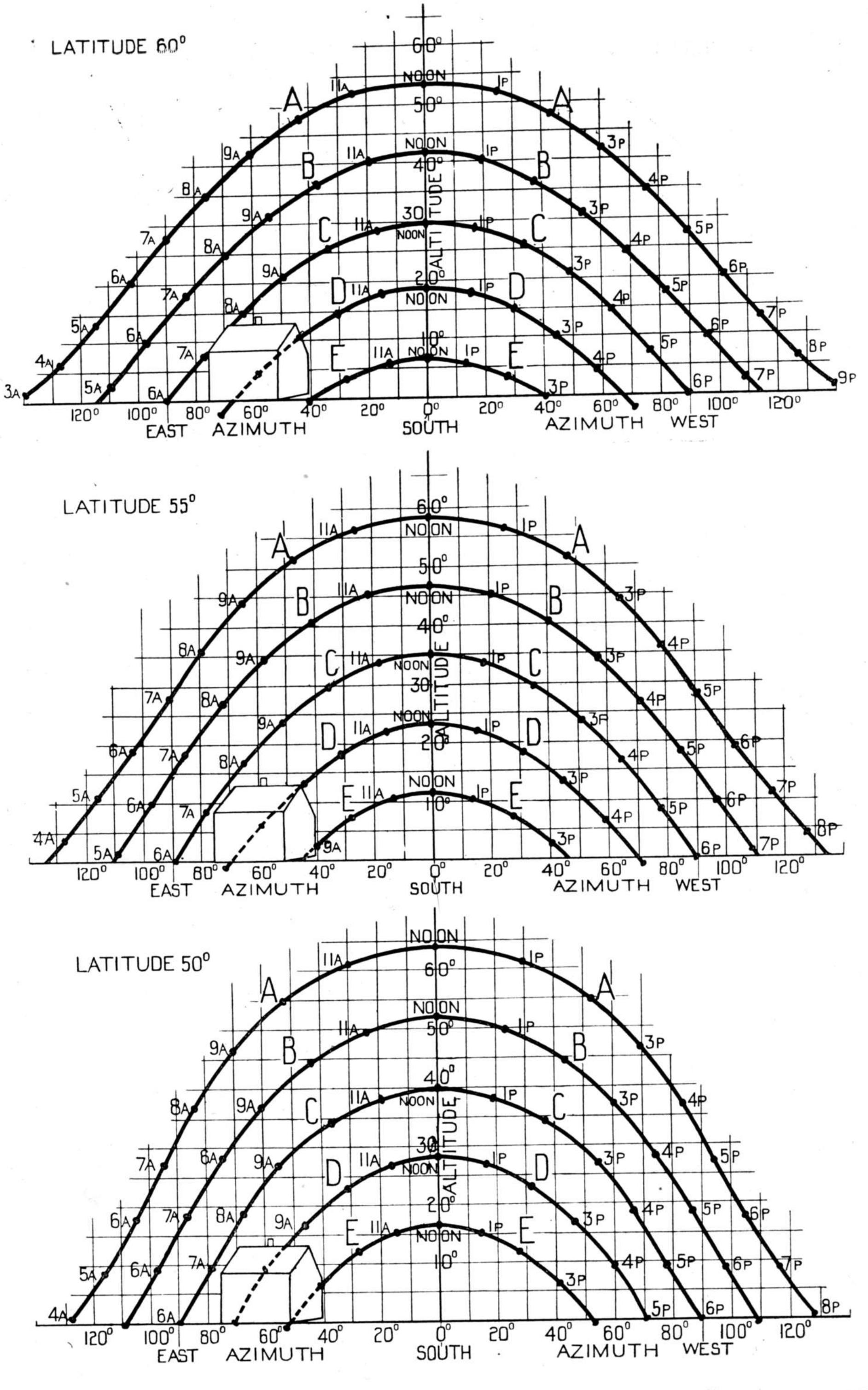
Auxiliary Apparatus for Adjusting Sunshine Recorders.

All these adjustments can be made with the help of the auxiliary apparatus shown in Plate IV. which will now be described. It consists of a table supported on three screw legs so that its height can be adjusted. Attached to the lower surface of the table are two bearings B_1 and B_2, in which two spindles of adjustable length, S_1 and S_2, turn. These spindles are connected with the semicircular plate A. To this plate an adjustable arm R is attached in such a manner that it can revolve in a plane parallel to that of the plate A, about a point in the line joining P_1 and P_2, the ends of the spindles, marked O in the figure and indicated on the instrument by a black dot. The plane containing O, P_1, P_2 and P_3, the tip of the arm R, can be rotated about the line P_1 P_2, and the amount of its rotation can be read off on the graduated arc T. On the table are two spirit-levels, one parallel to the line P_1 P_2, the other at right angles to it. By means of the former the line P_1 P_2 can be brought into the horizontal. The apparatus is so constructed that when the second level is set and the index on the arc T reads zero, the plane P_1 P_2 P_3 O is vertical, while when the index reads 90°, it is horizontal. Thus when both levels are set, the line P_1 OP_2 is horizontal and the plane P_1 P_2 P_3 O is inclined to the vertical at an angle which can be read off on the arc T.

To set up a recorder with the help of the auxiliary instrument we proceed as follows :—

If the instrument be of the type which is adjustable for latitude, set the index at the back of the bowl to the latitude of the place and clamp the bowl firmly in this position. Mount one of the brass equinoctial cards described below (p. 93) on the recorder.

Next adjust the spindles and the arm R on the auxiliary apparatus so that each of the lengths OP_1, OP_2, OP_3 is equal to 2·85 inches, the radius of the focal sphere, and set the index on the arc T to the latitude of the place. Clamp firmly in this position. Then place the auxiliary apparatus on the recorder and, with the help of the screw legs, adjust it so that the points P_1 and P_2 are opposite to the middle points of the six o'clock lines of the card and the point P_3 is opposite to the central line of the card. The

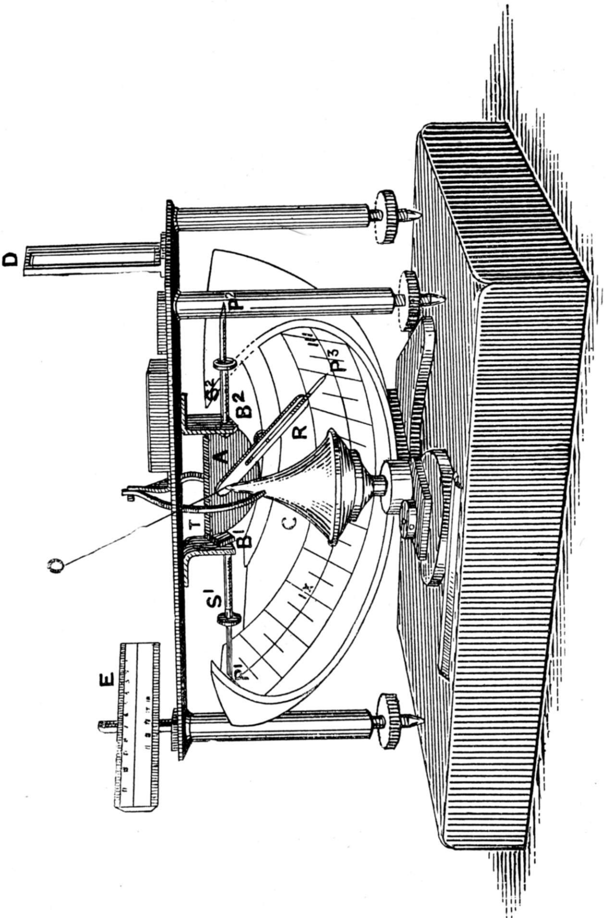


DIAGRAMS SHOWING THE ALTITUDE AND AZIMUTH OF THE SUN AT EACH HOUR (LOCAL APPARENT TIME) FOR PLACES IN LATITUDES 50°, 55°, 60°.

(For explanation *see* p. 83.)

PLATE IV.

To face page 85.



AUXILIARY INSTRUMENT FOR SETTING CAMPBELL-STOKES SUNSHINE RECORDER.

point O then indicates the position which the centre of the sphere should occupy, and if the arm R be rotated in the plane in which it is free to move it should travel along the central line of the card.

The adjustment for concentricity is made with the aid of a brass cone (C, Plate IV.) cut from a sphere of two inches radius. If this cone be placed on the pedestal, its apex marks the point which the centre of the sphere would occupy when in position. The adjustment is satisfactory when the apex of the cone is in contact with the dot O on the auxiliary apparatus.

Next place the recorder in the position selected for its exposure and turn it so that it faces approximately South. Replace the auxiliary instrument on it in the position described above and adjust the level of the recorder by placing suitable packing under it until both spirit-levels are set. The adjustments for latitude and level are then accurate. If the recorder has been previously adjusted for latitude it should now be found to be level when tested with a spirit-level placed (1) on the bowl, parallel to the line P_1 P_2 (2) at right angles to this position.

There remains the adjustment for meridian which can be made with the help of the sight and scale (D and E, Plate IV.), provided with the auxiliary apparatus and an ordnance survey map (6″ to the mile).

Mark on the map the exact position of the station and through it draw two lines at right angles to each other, one in the North to South direction, the other in the East to West direction. Select some prominent object which is easily visible from the recorder and of which the position on the map can be easily identified.

The object chosen should satisfy the following conditions; (*a.*) it should be as far away as possible; (*b*) it should be approximately East, West, North or South; (*c.*) it should be of well-defined shape, say a church spire or a factory chimney.

Let us suppose that an object on the Eastern side of the station has been selected. Measure on the map, with as much accuracy as possible, the **perpendicular** distance of the selected object from (1) the line drawn through the station in the East and West direction; (2) the line drawn through the station in the North and South direction. Divide the former distance by the latter, expressing the result as a decimal fraction.

In the slot on the West side of the auxiliary apparatus mount the sight bearing a hair, taking care that it is pushed firmly against its stop and that the marked side is placed against the marked slot. In the slot at the East side of the instrument mount the plain sight. Over the latter slip the ivory scale which will be found in the box, with the graduations facing the centre of the instrument.

Stand on the West side of the instrument with the eye at the same level as the sights, and then turn the recorder until the hair on the first sight, the point on the upper more open scale on the second sight, corresponding with the decimal fraction found above, and the distant object appear in the same straight line.

The adjustment for meridian is then satisfactory and **provided that none of the adjustments made above have been altered,** the instrument will be in perfect adjustment.

It is advisable to check the last adjustment by sighting more than one object in the manner described.

Should the object selected lie to the West of the station, the procedure is exactly similar, but the two sights must be interchanged.

If it lie to the North or South of the station the sights must be fixed in the slots on the North and South sides of the instrument; in this case the lower, more contracted, scale must be used. The method of procedure is exactly similar to that just described, but the distance of the object from the North and South line must be divided by its distance from the East and West line. [The more open scale is for use with the longer distance between the sights and *vice versa.*]

Additional Methods of setting a Sunshine Recorder.

As the auxiliary instrument described above is not always available, it will be advisable to consider methods of adjusting a recorder which do not involve its use.

Adjustment for Concentricity.

This adjustment should be made by the maker before the instrument reaches the observer. Instruments obtained through the Meteorological Office are tested and if necessary adjusted in the Office.

A rough test may be made with an ordinary sovereign whose diameter is very nearly equal to the distance from the card to the surface of the lens if the adjustment is correct.

To test the adjustment more precisely we may proceed as follows. From a piece of fairly stiff cardboard cut out a circle of 2·8 inches radius. On this disc of cardboard draw and cut out a concentric circle of radius 2·0 inches, the radius of the sphere. The ring of cardboard so formed can be fitted round a great circle of the sphere. Place the sphere, with the ring mounted symmetrically on it, on the pedestal of the recorder and, having placed a (straight) equinoctial card in the bowl under the central flanges, turn the sphere until the plane of the ring passes through the central white line on the cardboard, observe whether the edge of the ring is everywhere equidistant from the line. If the adjustment has been accurately made this should be the case.

The observer is warned against altering the position of the pedestal until he has thoroughly satisfied himself that further adjustment is needed as the method, unless very carefully applied, may easily show apparent errors of adjustment which do not really exist. The most easily made error is due to the placing of the ring round the sphere in such a manner that it does not form a great circle of the sphere. To guard against its occurrence the sphere should be reversed so that what was the lower surface of the ring becomes its upper surface. If the ring has been symmetrically mounted on the sphere it will be in the same relative position to the line on the card in both positions of the sphere. Several independent positions of the ring on the sphere should be tried before proceeding to adjust the pedestal.

Errors due to inaccuracies in the cutting of the ring will also lead to wrong results. To test this point revolve the sphere in such a way as to keep the ring in the same plane and observe whether the distance of the ring from each point on the card remains the same.

Adjustment for Level.

The adjustment for level in the East and West direction may be made after placing the recorder approximately in the required position with a spirit level placed on the top of the metal bowl, care being taken that the level is parallel to the front edge of the recorder. The slate base should not be used for levelling as the bowl may not be attached to it quite symmetrically. It is not necessary to level the instrument very accurately in the North and South direction for reasons which will appear when considering the adjustment for latitude.

The Adjustment for Meridian.

This adjustment will be considered next. In making it we start from the consideration that the position of the burn on the card when the instrument is in adjustment should indicate **local apparent time** on the time scale shown on the cards. It is

desirable to make the adjustment as near the hour of noon as may be convenient, as defects in the adjustments for level are of least importance at this hour.

The meaning of the term local apparent time has been explained on p. 12. We may here briefly recapitulate how to find the local apparent time corresponding with Greenwich Mean Time, *i.e.*, standard time of England and Scotland as shown by the clocks at railway stations, post offices, etc. We first require to obtain the local **mean** time corresponding with the selected Greenwich mean time. This may be done by subtracting or adding, according as the place is to the West or East of the meridian of Greenwich, a correction at the rate of 4 minutes of time for each degree of longitude.

To obtain local **apparent** time from local **mean** time, a further correction known as the *equation of time* must be applied. The amount of this correction for every third day of the year is given in the accompanying table; the amounts must be added to or subtracted from local mean time, according as the sign of the correction is + or −.

TABLE giving for every Third Day in Leap Year the Equation of Time to the nearest half minute, to be ADDED TO or SUBTRACTED FROM Local Mean Time according as the sign is + or —, in order to get Local Apparent Time.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	− 3½	−14	−12½	−4	+3	+2½	−3½	−6	+ ½	+10½	+16½	+10½
4	− 5	−14	−12	−3	+3½	+2	−4	−6	+ 1½	+11½	+16½	+ 9½
7	− 6½	−14½	−11	−2	+3½	+1½	−4½	−5½	+ 2½	+12½	+16	+ 8
10	− 7½	−14½	−10½	−1	+4	+1	−5	−5	+ 3½	+13	+16	+ 7
13	− 9	−14½	− 9½	− ½	+4	0	−5½	−4½	+ 4½	+14	+15½	+ 5½
16	−10	−14½	− 8½	+ ½	+4	− ½	−6	−4	+ 5½	+14½	+15	+ 4
19	−11	−14	− 8	+1	+3½	− 1	−6	−3½	+ 6½	+15	+14½	+ 2½
22	−11½	−14	− 7	+1½	+3½	− 2	−6	−2½	+ 7½	+15½	+13½	+ 1
25	−12½	−13½	− 6	+2	+3½	− 2½	−6	−2	+ 8½	+16	+12½	− ½
28	−13	−13	− 5	+2½	+3	− 3	−6	−1	+ 9½	+16	+11½	− 2
31	−13½	..	− 4	+3	+2½	− 3½	−6	0	+10½	+16½	+10½	− 3½

We will proceed to give an example. Suppose that it is desired to determine the local apparent time corresponding with noon Greenwich Mean Time, at a place situated in longitude 3° W. of Greenwich on August 7th. To reduce **Greenwich** mean time to **local** mean time the correction will amount to $3 \times 4 = 12$ minutes, and, as the place lies to the West of the meridian of Greenwich, this amount must be subtracted. We have thus :—

Noon G.M.T. = 11 hrs. 48 mins. L.M.T.

From the table we find that the equation of time on August 7th is − $5\frac{1}{2}$ minutes and hence :—

Noon G.M.T. = 11 hrs. 48 mins. − $5\frac{1}{2}$ mins. = 11 hrs. $42\frac{1}{2}$ mins. local apparent time.

In other words local apparent time is $17\frac{1}{2}$ minutes behind Greenwich Mean Time, and the burn should fall on the hour marks on the cards of the recorder at $17\frac{1}{2}$ minutes **past** each hour by Greenwich Mean Time.

For places lying to the East of the meridian of Greenwich the calculation is made in a similar manner, but the correction for longitude must be added instead of subtracted.

In Ireland the standard time of the country, as indicated by the clocks at railway stations, etc., is referred to Dublin. If the observer works from this standard he must accordingly apply a correction for longitude corresponding with the difference in longitude between his station and Dublin. Greenwich Mean Time is however shown by the red minute hand attached to the clocks in Irish post offices.

The Adjustment for Latitude.

In the case of instruments in which the position of the bowl with regard to the base can be altered, this adjustment is made by sliding the bowl in its socket until the arrow head, Plate III., is opposite the point on the graduated arc along which it moves, corresponding with the latitude of the place. The slate base must then be levelled in the North and South direction.

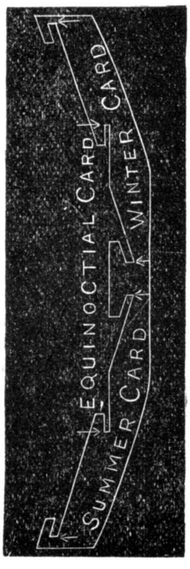


FIG. 25.

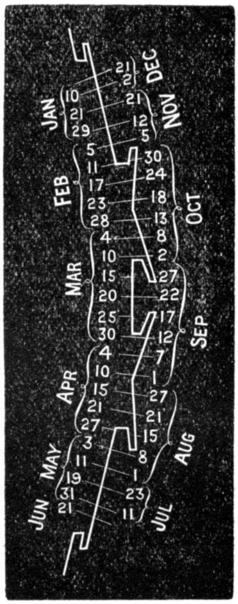


FIG. 26.

The adjustment may be tested, and in the case of instruments with fixed bowls, may be made with the help of the diagram in Fig. 26, which shows the position on the bowl which the trace should occupy on each day of the year. As the positions of the flanges is found to vary slightly in different bowls the position of the trace should always be referred to the central point of the diagram and not to the position of the flanges.

Three cases may arise.

Case 1. If the adjustment is made on the day of either equinox, *i.e.*, on the 21st of March or September, the burn should fall on the central white line on an equinoctial card, and if necessary the recorder must be tilted in the North and South direction, without disturbing the level in the East and West direction, until this is the case.

Case 2. If the adjustment is to be made on any other day between March 1st and April 12th or between September 1st and October 12th, *i.e.*, during the period within which the equinoctial cards are in use, adjust a pair of compasses or dividers until the distance between the ends of its legs is equal to the distance on the diagram Fig. 26, between the point on which the trace should fall at the equinoxes (the central point of the diagram) and the point on which it should fall on the day in question. Set off this length on an equinoctial card at right angles to the central white line on the card. A line drawn on the card through the point so found, and parallel to the central line, will indicate the position which the burn should occupy, and as before the adjustment may be made by tilting the recorder.

Case 3. If the adjustment is to be made on any other day of the year, first place an equinoctial card in the recorder, and mark on the latter the position on the "noon" line which is exactly opposite the central white line of the card. Remove the equinoctial card and replace it by a summer or a winter card according to the season. Set a pair of compasses so that the distance between its points is equal to the distance between the central point of the diagram, Fig. 26, and the point which the burn should occupy on the day in question. Place one leg of the compass on the mark made on the bowl and bring the other on to the noon line of the card in the recorder. The point on the card so found indicates the position on the card which the burn should occupy at noon, local apparent time, and a line drawn through this point parallel to the central line on the card will show the position along which the trace should fall. The line may be most conveniently drawn by keeping the compasses fixed and drawing the card through the flange, allowing the point of the compass leg to mark it as it passes. As before, tilt the recorder in the North and South direction until the burn falls on this line.

Attention may be drawn to the fact that at the time of the solstices the rate of change of the sun's declination is very slow, and hence the position of the trace on the cards at these times will differ very little from day to day. For a period of nearly two months, about the time of mid-summer or mid-winter, it varies through no more than one-tenth of an inch.

If all the adjustments have been made satisfactorily, the trace should be parallel with the central lines on the cards. Want of parallelism most probably indicates defects in the adjustments for level or meridian. If the adjustment for latitude is faulty the burn may fall on one of the flanges instead of on the card at certain times of the year.

If the lens is in good focus, *i.e.* if the adjustment for concentricity is satisfactory, the trace should be narrow and well defined at its edges, and the card should be scored whenever the sun shines brightly even if it be only for a few seconds.

When the observer has satisfied himself that the recorder is accurately set he should fix it firmly in position to prevent its being accidentally displaced when changing the cards. At many stations the slate base is fixed in a bed of cement.

Management of the Instrument.

When once the recorder has been set up, it requires little attention beyond that involved in changing the cards each day. The glass ball and the grooves in which the cards slide should be regularly cleaned. If snow or hoar-frost settles on the recorder it should be removed at once.

A card should be inserted every day even if no sunshine has been recorded. A blank card affords evidence that the day has been overcast.

If possible the cards should be changed after sunset each day. If this be impracticable any other hour may be selected, but an hour

having been once fixed upon it should be adhered to as far as possible. If the cards are changed before sunset there is danger of two traces overlapping and to prevent confusion the exact local apparent time of insertion, as indicated by the burn, should be written on the face of the card. If the sun is shining at the time when a fresh card is being inserted, the observer should shade the ball in order to prevent a false score being made.

When inserting a card care must be taken that the XII line on it coincides with the "noon" mark on the bowl.

If after rain, a card cannot be withdrawn without tearing it, it should be carefully cut out by drawing a sharp knife along the edge of one of the flanges.

Every card should have clearly written on it the name of the station, the date (day, month and year) of the record and, if the cards are changed before sunset, the time of insertion and withdrawal. This should be done immediately after the card has been withdrawn from the instrument.

Observers in connexion with the Meteorological Office are particularly requested to forward their cards as soon as possible after the close of each month to

The Director,
Meteorological Office,
South Kensington,
London, S.W.

In packing for transmission through the post the cards should be kept flat and not be folded. Suitable boxes or envelopes can be obtained from the Office.

Types of Cards.

Three types of card are supplied for use with the instruments.

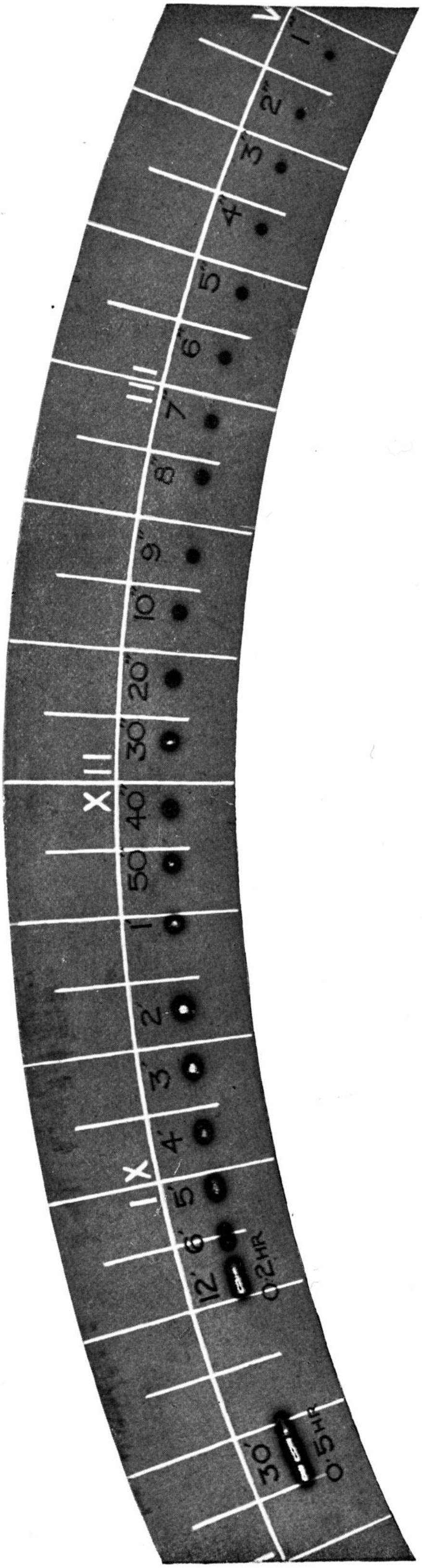
(1). The long curved cards are to be used during summer from the **13th of April** to the **31st of August** inclusive; they should be inserted, with their convex edge uppermost, beneath the flanges marked "summer card" in Fig. 25.

(2). The short curved cards are to be used during winter from the **13th of October** to the **last day of February** inclusive; they should be inserted, with their concave edges uppermost, beneath the flanges marked "winter card" in Fig. 25.

(3). The straight cards are for use about the times of the equinoxes from the **1st of March** to the **12th of April** and again from the **1st of September** to the **12th of October**, both periods inclusive; they should be inserted beneath the central pair of flanges marked "equinoctial card" in Fig. 25. When inserting the equinoctial cards care must be taken that the *hour figures are erect*, otherwise the morning sunshine will be recorded on the portion of the card intended to receive the afternoon record and *vice versâ*. If the cards are properly inserted the line marked IX will be on the western side of the recorder (the left-hand side when looked at from the front) in all cases.

To face page 91.

PLATE V.



RECORDS OBTAINED BY EXPOSING A CAMPBELL-STOKES SUNSHINE RECORDER FOR MEASURED INTERVALS VARYING FROM ONE SECOND TO THIRTY MINUTES.

The duration of the exposure of the separate burns increases from right to left of the diagram.

Length of Cards.

The cards issued by the Meteorological Office are cut to the smallest length compatible with their being used in all latitudes in the British Isles. If other cards are used attention must be paid to the following point. If the ends of the equinoctial cards are left projecting over the top of the bowl they will intercept the sun's rays at sunrise and sunset and cause loss of record. The following table gives the apparent times of sunset and sunrise within the limits of latitude of the British Isles on the limiting days on which the equinoctial cards are used :—

—	March 1st or October 12th.					April 12th or September 1st.				
Latitude	49°	53°	56°	58°	60°	49°	53°	56°	58°	60°
	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.
Time of Sunrise ...	6·31	6·36	6·40	6·43	6·47	5·17	5·10	5·4	5·0	4·55
Time of Sunset ...	5·29	5·24	5·20	5·17	5·13	6·43	6·50	6·56	7·0	7·5

The distance of the trace from the central line of the card on these days is shown on Fig. 26, and, knowing the latitude of his station, the observer will be able to determine the extreme positions on his cards on which the record might fall, if the sun shone sufficiently strongly at the time of sunset or sunrise. The cards should be cut off along lines joining these points.

In the cases of the summer and winter cards the projecting ends are not as a rule in a position to intercept the sunshine but if very long cards are used the projecting ends should be removed. The following table gives the times of sunrise and sunset at the solstices and will enable the observer to determine the limits to which the cards should be shortened.

—	Summer Solstice.					Winter Solstice.				
Latitude	49°	53°	56°	58°	60°	49°	53°	56°	58°	60°
	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.	h.m.
Time of Sunrise ...	3·56	3·34	3·14	2·57	2·38	7·50	8·15	8·34	8·50	9·7
Time of Sunset ...	8·4	8·26	8·46	9·3	9·22	4·10	3·45	3·26	3·10	2·53

Tabulation of the Cards.

The amount of bright sunshine should be expressed in hours and decimal fractions of an hour. The figures should not be carried beyond the first place of decimals (0·1 hour = 6 minutes).

The points on which observers have generally asked for information have been two :—

(1.) How to deal with cases in which the scorch is *faint*, such as is usually the case near sunrise and sunset, or when the sun is shining through a slight haze.

(2.) How much of the trace to measure when the sun has been shining *brightly* but *intermittently*, or when a strong burn has been abruptly stopped.

In the first of these cases it is recommended that the whole of the trace, *as far as it can* FAIRLY *be seen*, should be measured, the measurement being carried right to its extreme ends.

In the second case it must be remembered that there is always a slight lateral extension of the trace, due to the fact that the image of the sun formed by the sphere has an appreciable diameter and also to smouldering of the card. In consequence the trace will be very nearly as long for a few seconds of sunshine as for two or three minutes. In Plate V. actual traces obtained by exposure for measured intervals from one second to half an hour are reproduced by photography and show how much lateral spread there may be in cases of intermittent sunshine. For these effects a slight allowance should be made, and the measurement should not in such cases be carried to the extreme limits of each of the burns.

The burns shown in Plate V. show that a close approximation to the true duration of bright sunshine can be obtained if the measurement is carried to the centre of the semicircular end of each part of the trace, but in practice the allowance made for the lateral extension of the burn is considerably smaller than this. To introduce a change in the method of procedure would involve inconvenience to observers, and, moreover, the results obtained would not be comparable with those for previous years from which the adopted average values have been computed. As one of the primary objects of sunshine measurements is to enable us to compare the results from different places or for different periods, it is not considered desirable to modify the practice which has prevailed hitherto. Details of the experiments referred to above will be published in a report, now in course of preparation, on the Climatology of the British Isles. In order to secure uniformity in the method of estimating, it is desirable that a central authority should have an opportunity of examining the tabulations made at different stations and for this reason observers who desire their returns to be included in official publications are required to send their cards to the Meteorological Office for inspection at the end of each month.

A convenient method of evaluating a trace is to place the edge of a sheet of paper along it and to mark on the paper with a sharp pencil, lengths equal to the lengths of successive burns. The paper is slid along the trace so that these lengths form a continuous line, the addition being thus done mechanically. The length of the line is then read off on the special scale* shown in Plate VI. When reading off, the paper must be placed against the line on the diagram corresponding with the date of the record. All records on equinoctial cards must be measured along the line so marked. The length of the burn may also be read off on the time scale shown on the cards, but in the cases of the curved summer and winter cards, on which the length of an hour space is not the same throughout the whole width of the card, care must be taken to measure along the portion of the card on which the burn falls on the day in question. On this account it is better to use the specially constructed scale of Plate VI.

Sunshine Recorders for other Latitudes.

The dimensions of sphere and bowl and the positions of the flanges are the same in all instruments and a slight modification in the manner of cutting the ends of the bowl is the only change which need be made in the main features of the recorder unless it is required for exceptionally high latitudes.

*** Copies of the scale, specially printed for use in measuring the sunshine traces, can be had on application to the Meteorological Office.**

SCALE FOR MEASURING THE DURATION OF BRIGHT SUNSHINE RECORDED BY CAMPBELL-STOKES RECORDERS OF STANDARD DIMENSIONS.

WINTER CARD	SOLAR DECLIN-ATION	HOURS 0 1 2 3 4 5 6	SUMMER CARD
Dec 11 to Jan 1	23°		June 10 to July 3
Dec 2 and Jan 10	22°		June 1 and July 12
Nov 26 and Jan 16	21°		May 25 and July 18
Nov 21 and Jan 21	20°		May 20 and July 24
Nov 17 and Jan 25	19°		May 16 and July 28
Nov 13 and Jan 29	18°		May 12 and Aug 1
Nov 9 and Feb 1	17°		May 8 and Aug 5
Nov 6 and Feb 5	16°		May 4 and Aug 8
Nov 3 and Feb 8	15°		May 1 and Aug 12
Oct 31 and Feb 11	14°		Apr 28 and Aug 15
Oct 28 and Feb 14	13°		Apr 24 and Aug 18
Oct 25 and Feb 17	12°		Apr 21 and Aug 21
Oct 22 and Feb 20	11°		Apr 19 and Aug 24
Oct 19 and Feb 23	10°		Apr 16 and Aug 27
Oct 16 and Feb 25	9°		Apr 13 and Aug 30
Equinoctial Card			Equinoctial Card

2755.

Equinoctial card, 6 hours = 4·50 ins. Curved cards { *Declination 8° 6 hours = 4·50 ins.* / *Declination 24° 6 hours = 4·15 ins.* }

The angle at which the bowl is set with regard to the base of the instrument is subject to great changes with latitude since the plane cutting an equinoctial card along its central white line must be inclined to the vertical at an angle equal to the latitude. In the tropics this involves placing the bowl more or less directly under the sphere, and hence the method of supporting the latter on a pedestal attached to the base of the instrument cannot be adopted. The most usual method of supporting the sphere under these circumstances is to clamp it between two jaws which close on it in the direction of the polar axis.

The adjustments and the methods of making them are similar for all latitudes with the exception that in the southern hemisphere the recorder must face towards the North instead of towards the South. The cards are identical in point of curvature and length of scale divisions in both hemispheres and for all latitudes. The numbers indicating the hours must however be reversed on cards intended for use in the southern hemisphere and the IX. a.m. and the III. p.m. marks must be interchanged. Unless this be done the morning sunshine is received on the portion of the card intended for the afternoon record and *vice-versâ* and subsequent confusion might arise. If cards for the wrong hemisphere are used for any reason, the hour marks should be corrected by hand on each card.

The length of the cards varies greatly with latitude. At the equator, summer, equinoctial and winter cards are all of equal length. For other latitudes the observer can calculate the lengths to which he should cut each type of card with the help of the diagram Fig. 26, page 88 and a table giving the times of sunrise and sunset for his particular latitude at different times of the year. A table giving the information for all latitudes is contained in Whitaker's Almanack. Cards for use with recorders of standard dimensions, suitable for all latitudes and for use in either hemisphere, can be obtained through the Meteorological Office.

Specification of Standard Dimensions of Campbell-Stokes Sunshine Recorders for use in connexion with the Meteorological Office.

For the purpose of testing the bowl, specially graduated strips of brass, equivalent to the three patterns of cards used in the recorder, and each 0·02 inch thick, will be used.

The width of the equinoctial card is to be 1·56 inches, and of the summer and winter cards 1·26 inches.

The radius of the central arc of the summer and winter cards is to be 10·05 inches.

A time scale in which 12 hours are represented by 9·00 inches, and also a central line parallel to its edges are to be engraved upon the strip representing the equinoctial card. Central lines only are required upon the curved cards. In placing the metal strips for measurement in case there is any "play," the position for measurement will be when the lower edge is pressed down to the bottom of its groove.

The Bowl.

(1) The diameter of the bowl, measured between the centres of the 6 o'clock marks on the metal equinoctial card when in its place, is to be 5·73 inches (± 0·01 inch).

(2) The middle line of the equinoctial card when in its place must lie equidistant from the top and bottom flanges of the bowl.

(3) The distance between the exposure edges of the upper winter flange and the lower summer flange must not be less than 2·45 inches, nor exceed 2·50 inches.

(4) The distances from the middle line on the equinoctial card, to the middle lines on the summer and winter cards are to be 0·70 inch (± 0·02 inch).

(5) The inclination of the summer card, in place, to the winter card, in place, is to be $32° \pm \frac{1}{2}°$, symmetrically arranged with regard to the equinoctial card.

(6) The section of the supporting surface by a plane through the polar axis is to be as represented in the accompanying drawing (Fig. 27) :—

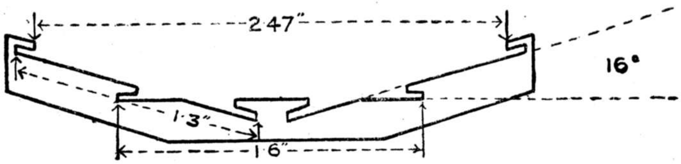


Fig. 27.

The Sphere.

(1) The material for the sphere must be "Crown" glass.

(2) The glass should be colourless, or of a very pale yellow tint.

(3) The standard diameter of the sphere is 4 inches. When held with a given diameter at any angle, the sphere must pass through a circular hole 4·01 inches, in diameter, cut in a brass template, but not through a similar hole 3·99 inches in diameter.

(4) The weight of the sphere must lie between 2·92 lbs. and 3·02 lbs.

(5) The focal length from the centre of the sphere to the geometrical focus for parallel rays should be between 2·96 inches and 2·99 inches.

Mounting of the Bowl and Sphere.

(1) In view of the use of recorders in different latitudes, it is an advantage that the bowl should be so mounted as to be capable of being adjusted for latitude without moving the base.

(2) The "belt" from which the bowl is made should be so cut that when the bowl is adjusted for its mean latitude the plane of the cut shall be approximately horizontal.

(3) The mounting of the sphere must be such as will permit of its centre being readily adjusted to the centre of the bowl.

PART III.

ADDITIONAL INSTRUMENTS AND OBSERVATIONS.

Evaporimeters.

The amount of evaporation from a land surface depends greatly on the nature of that surface. Evaporation experiments as conducted at meteorological stations have for their object the determination of the loss of water per unit area from a water surface such as that of a reservoir or lake. Experience has shown that evaporimeters of small size give unsatisfactory results as the values obtained are always too high on account of the heating of the apparatus, which must be freely exposed to sun as well as to wind.

The tank used should be not less than six feet long and six feet wide, and its depth should be two feet. It may be made of galvanised iron. On account of its size it is necessarily heavy and awkward to handle. Before being sunk into the ground the tank should be carefully examined to make sure that no joints have been started during transportation, and that it is perfectly watertight. This may be done by mounting it on planks so that all parts can be easily examined, and filling it nearly full with water.

The tank is then sunk into a hole dug out from a level grass plot which is freely exposed to sun and wind. To make sure that the tank lies evenly, and free from strains, the bottom of the hole should be flooded before the tank is lowered into it. The space between the sides of the tank and the hole is filled with earth and flooded so as to make it solid, and finally turf is laid close up to the sides of the tank. The rim of the tank should rise about one and a half inches above the grass, which should be kept short. The tank is then filled with water to within about two and a half inches from the top.

The observations are made by noting the difference in level of the water surface from day to day. If rain has fallen its amount must be determined from the record of an ordinary rain gauge, and allowed for in computing the amount of evaporation. The level of the water surface must be determined accurately to within 0·01 inch, the degree of accuracy required in rainfall measurements. In the most modern form of apparatus the observation is made by means of a float. In order to protect this float from the action of the ripples set up by the wind on the surface of the water in the tank, it must be enclosed in a cylinder of slightly greater diameter, with a small hole drilled in its base. The water level is the same inside and outside this cylinder, but the ripples cannot affect the water in the "still water pond." By means of a chain passing over a pulley, the float is made to actuate an arm which moves over an arc graduated directly in terms of the level of the water in the tank. By making the arm sufficiently long an open scale can be obtained, on which reading to the nearest 0·01 inch presents no difficulty.

Observations should be made each morning at 9 a.m., the hour for observing rainfall and in conformity with the practice adopted in the entry of rainfall data, the amount of evaporation should be entered in the register as referring to the 24 hours commencing at 9 a.m. The following scheme of entry is suggested :—

Date. June.	Water level.	Fall of level in 24 hours.	Rainfall.	Evaporation.	Remarks.
	in.	in.	in.	in.	
1 ...	0·83	0·04	—	0·04	
2 ...	·79	—0·29	0·35	·06	
3 ...	1·08	—0·47	·50	·03	
4 ...	{1·55 1·12	+0·07	—	·07	Excess of water removed. New reading, 1·12.
5 ...	1·05	·07	—	·09	
6 ...	0·96	·08	—	·08	
7 ...	0·88	—	—	—	
etc.					

The water surface should not be allowed to fall more than four inches below the rim of the tank and on the other hand it should not rise to within less than two inches of the rim. Water must therefore be added or removed from time to time according as evaporation or rainfall has been great. The operation should be performed immediately after taking the morning observation and a new reading should be taken immediately after it is completed in order to determine the value with which the next day's reading is to be compared.

During frosty weather the ice surface should be broken up before a reading is taken and all ice adhering to the sides of the tank must be scraped off and put back in the tank. Care must be taken that no ice is removed from the tank and that the float moves quite freely in its containing cylinder. The ice ought to be broken from time to time as it forms, because if allowed to become thick it may strain the tank and cause it to leak.

It is hardly necessary to point out that adequate precautions must be taken to prevent the tank being interfered with either by unauthorised persons or by animals.

Observations of the Normal Electrical Phenomena of the Atmosphere.

For a brief account of the normal electrical phenomena of the atmosphere, reference may be made to a paper by G. C. Simpson in the Quarterly Journal of the Royal Meteorological Society. (Vol. XXXI., 1905, p. 295.)

The quantities which form the usual object of measurement are :—

(1.) The vertical potential gradient.

(2.) The electrical dissipation.

(3.) The ionisation of the atmosphere.

For a description of the instruments used in determining these quantities and of the methods of using them, reference must be made to text books of physics.

Autographic Thunderstorm Recorders.

The Hertzian waves set up by lightning flashes may be utilised for obtaining an autographic record of their occurrence.

An insulated wire, about 30 yards long, acts as a collector of the Hertzian waves. It is connected with a coherer. The hammer used to reset the coherer automatically after a flash has passed may be connected with a pen writing on a revolving drum driven by clockwork.

For particulars regarding the construction of apparatus of this nature, see *Meteorolog. Zeitschr.* 1903, p. 462, or Monthly Weather Review (Washington) Vol. XXXII., 1904, p. 273.

Radiation.

The black bulb thermometer *in vacuo* (see p. 31) is used at many climatological stations for obtaining an indication of the intensity of the sun's radiation but the records are not very satisfactory for the reasons (1) it is not possible to define the physical quantity measured by the instrument (2) the readings of different instruments are not comparable. Experience has shown that two instruments of similar construction do not necessarily give the same readings when exposed side by side and moreover the differences between two instruments do not remain constant.

Nocturnal radiation from the earth to space is estimated with the grass minimum thermometer. Though the physical interpretation of the readings of this instrument presents difficulties, the records give useful climatological information upon the occurrence of ground frosts.

Ångström's Compensating Pyrheliometer.

The following resolutions regarding the organisation of observations of radiation were adopted by the International Conference of Directors of Meteorological Offices and Observatories held at Innsbruck in 1905 :—

"The Conference resolves— :—

"(1) That measurements of the total solar radiation be made at central observatories, and at other stations which possess the facilities to do so, regularly each day at 11 a.m., or from 11 a.m. to 1 p.m. Ångström's compensation pyrheliometer should be used exclusively for these measurements.

"(2) That measurements of terrestrial radiation be made each evening at 10 p.m. or from 10 p.m. to midnight, also exclusively with Ångström's compensation pyrheliometer."

The following account of M. Ångström's apparatus and of the method of using it is taken from M. Violle's report on Atmospheric Radiation made to the International Meteorological Committee at its meeting in St. Petersburg in 1899.

Ångström's compensating pyrheliometer (1893).*—M. Ångström has communicated to the Royal Society of Upsala the description of

* *Actes de la Société royale des Sciences d'Upsal*, 1893 ; and *Annalen der Physik und Chemie*, Neue Folge, Vol. LXVII., p. 633, 1899.

a compensating pyrheliometer, founded on a principle entirely different from that employed in his first instrument. He takes as his calorimetric body two thin strips of metal, identical in every way, and then exposes one to the rays of the sun, while through the other, kept in the shade, he passes an electric current, the intensity of which is regulated so that the heating of the two strips is the same. He secures this agreement by so adjusting the current that two identical thermo-electric elements in contact with the two strips compensate each other on a sensitive galvanometer. The energy of the incident radiation received by the exposed strip in unit time is equal to that communicated to the screened strip by the electric current.

Let q be the radiation per second per square centimetre, b the width of the strips, a the absorbing power of their blackened surface, r their resistance per unit of length, and i the intensity of the compensating current.

We have

$$b\,a\,q = \frac{r\,i^2}{4\cdot 18}$$

From this

$$q = \frac{r\,i^2}{4\cdot 18\,b\,a}\left(\frac{\text{calorie}}{\text{second}}\right)$$

or

$$Q = \frac{60}{4\cdot 18}\,\frac{r\,i^2}{b\,a}\left(\frac{\text{calorie}}{\text{minute}}\right).$$

If the intensity of radiation be expressed in watts per square centimetre, the equation becomes

$$q = r\,i^2/(b\,a).$$

This method does away with all corrections for cooling. We determine b, a, and r (as well as the variation of r with temperature).

In order to make an absolute measure we have only to observe i.

The metal strips are of platinum or manganin, with a thickness of 1 μ or 2 μ., and their breadth is 2 mm. On its lower surface each has a junction of *constanton (or nickel)*—copper. Their anterior surfaces are blackened. The strips are mounted, side by side, at the bottom of a tube containing several diaphragms. In front of the tube there is a movable perforated screen which allows the radiation which is to be measured to fall alternately on one strip or the other. The bottom of the tube carries four terminals, two for the circuit of the thermometric junctions in which is included a very sensitive galvanometer, and the two others for the circuit of the compensating current, which comprises a Daniell's or Leclanché's element (or, better still, an accumulator), a sliding contact resistance box, and a milliammeter (or, better, a special electrodynamometer). A commutator permits the putting one or other of the strips in the circuit.

The strips are cut off on the dividing engine and their breadth b is thus known accurately. The resistance per unit of length r, is measured by balancing with a Lippmann capillary electrometer, the difference of potential (1) between two knife edges resting at a known distance apart on the strip against (2) that between two contacts, one fixed, the other movable, on a standard wire, both strip and wire being included in the same circuit. In order to take account of the variation of r with temperature, M. Ångström determines

separately the effect of the initial temperature of the wire (the temperature t of the surrounding space) and that of the heating due to the passage of a current of intensity i. He thus knows the resistance $r_{t,i}$ in the conditions of the experiment. Direct observations have shown that the absorbing power a of the surfaces blackened by Crova's method may be taken as equal to 0·985.

The course of an experiment is as follows :—The apparatus being adjusted for direction, first make sure that the radiation falling simultaneously on the two strips does not alter the zero position of the galvanometer connected with the thermometric junctions. Then arrange the screen so that only one of the strips is exposed to the sun, and, at the same time, pass through the other strip the compensating current, the intensity of which is regulated so as to bring back the galvanometer to zero. Read the intensity of the current by the milliammeter (or by the special electrodynamometer). Then change the position of the screen and of the commutator so as to reverse the action of the two strips, and make another measurement. Then revert to the original arrangement and take a third reading. Here is an example of an observation made by M. Ångström on the top of the Peak of Teneriffe (3,700m.) on June 25, 1896, at noon. The right-hand strip D_1 having been first exposed, and then the left-hand one G, and finally the right-hand one again D_2.

	i^2
D_1	0·0704
G	0·0713
D_2	0·0702

$$\text{Mean } \frac{D_1 + D_2 + 2G}{4} = 0{\cdot}0708.$$

The temperature of the tube enclosing the whole being 21°, $r_{t,i} = 0{\cdot}3614$ and we have $Q = 1{\cdot}626$ gramme-calories per cm.^{2} per min.
$= 0{\cdot}114$ watts/cm.^{2}

A very interesting double series was obtained a few days later, on July 3, by M. Ångström at Guimar (300 m.), and by his assistant, M. Edelstam, at Alta Vista (3,252 m.), between 5h. 30m. a.m. and 5h. 13m. p.m. The series of values obtained at Alta Vista were remarkably regular. The readings at noon were :—

Guimar ...	$Q = 1{\cdot}384$ gm. cal. per cm.^{2} per min.
	$= {\cdot}097$ watts/cm.^{2}
Alta Vista ...	$Q = 1{\cdot}618$ gm. cal. per cm.^{2} per min.
	$= 0{\cdot}113$ watts/cm.^{2}

Several improvements have been introduced into the apparatus since this date. Instructions for manipulation are issued with each instrument.* It is desirable that two sets of strips be procured, one for regular use, the other for use as a standard of comparison.

* The instruments in use up to date have been made by M. Rose, the mechanician to the University at Upsala, and the late M. Ångström himself superintended the determination of their constants. (See Report of the eighth meeting of the International Meteorological Committee at Paris in 1907, pp. 61, 62).

Michelson's Actinometer.

A new instrument for the measurement of solar radiation devised by W. A. Michelson, of St. Petersburg, depending upon the bending of a bimetallic lamina in the sun's rays, is described in the June number of the Meteorologische Zeitschrift, 1908, p. 246.

Aerological Research.

Observations of the Upper Air by means of Kites, Registering Balloons (Ballons Sondes), or Pilot Balloons.

In recent years much progress has been made in the investigation of the upper air by observers in many countries acting in co-operation through the agency of the Commission for Scientific Aeronautics appointed in 1896 by the International Meteorological Committee. In this investigation, meteorographs, *i.e.*, instruments for obtaining autographic records of the meteorological elements, and other apparatus are generally constructed at the different centres for aerological research. Instruments of any of the types in use can generally be obtained from these centres through the courtesy of the respective directors.

A detailed account of the instruments employed and the methods of working in this country will be found in an official publication of the Meteorological Office, entitled "The Free Atmosphere in the Region of the British Isles," M.O. 202 and Geophysical Memoirs, No. 2.

For particulars as to the use of Pilot Balloons, *see* "The Structure of the Atmosphere in Clear Weather," by C. J. P. Cave, M.A.

Form 355.

APPENDIX I.

SPECIMEN

OF

METEOROLOGICAL RETURN

FROM

NORMAL CLIMATOLOGICAL STATION.

(Station of the Second Order of the International Classification.)

I. Observations recorded at 9 a.m. (= 9 h), Local Mean Time.

II. „ „ 3 p.m. (=15 h), Local Mean Time.

III. „ „ 9 p.m. (=21 h), Local Mean Time.

Station, Buxton.

Month and Year, January, 1909.

Attached Thermometer and Barometer as read. I. 9 a.		II. 3 p.		III. 9 p.		Date.	Air Pressure at Mean Sea Level, expressed in inches of Mercury at 32°F., and Standard Gravity Latitude 45°. I. 9 a.	II. 3 p.	III. 9 p.	Air Temperature, degrees F. I. 9 a. Dry.	Wet.	II. 3 p. Dry.	Wet.	III. 9 p. Dry.	Wet.	III.* Max.	Min.	Humidity. Dep. of Wet. I. 9 a.	II. 3 p.	III. 9 p.	Vapour Pressure. I. 9 a.	II. 3 p.	III. 9 p.	Percentage. I. 9 a.	II. 3 p.	III. 9 p.	Wind, Direction and Force. I. 9 a.	II. 3 p.	III. 9 p.
°	ins.	°	ins.	°	ins.		ins.	ins.	ins.	°	°	°	°	°	°	°	°	°	°	°	in.	in.	in.						
52·1	29·526	51·3	29·534	54·3	29·555	1	30·60	30·61	30·62	42·2	41·8	43·2	42·1	42·2	41·5	45	40	0·4	1·1	0·7	·26	·26	·25	96	91	94	Calm 0	SW 1	WSW 2
53·2	·572	53·5	·538	54·8	·560	2	·64	·60	·62	43·3	42·6	46·3	45·1	44·6	43·7	48	40	0·7	1·2	0·9	·27	·29	·27	95	92	94	WSW 1	WSW 2	W 1
54·5	·574	55·8	·556	57·4	·610	3	·64	·61	·66	44·6	43·6	47·5	46·0	45·1	44·5	49	43	1·0	1·5	0·6	·27	·29	·29	93	89	95	W 1	W 3	W 1
53·8	·658	53·4	·642	56·2	·646	4	·73	·71	·71	42·5	40·7	43·2	41·5	41·8	40·6	47	41	1·8	1·7	1·2	·23	·24	·24	86	87	91	WNW 1	Calm 0	Calm 0
54·5	·570	53·7	·486	54·1	·448	5	·65	·56	·53	38·8	36·4	41·3	38·2	34·6	33·1	43	34	2·4	3·1	1·5	·19	·20	·17	81	76	85	S 1	SSE 1	WSW 2
53·1	·354	53·6	·332	54·2	29·298	6	·43	·40	30·37	37·0	35·5	40·1	39·6	37·3	35·1	42	33	1·5	0·5	2·2	·19	·24	·18	87	96	82	W 1	W 1	WNW 4
51·0	29·168	50·4	29·002	52·7	28·854	7	30·24	30·07	29·92	37·3	36·3	38·4	37·1	35·0	34·6	40	35	1·0	1·3	0·4	·20	·21	·20	92	89	96	WNW 4	W 4	NW 4
51·5	28·820	50·8	28·860	51·8	29·086	8	29·89	29·92	30·16	34·2	33·6	37·6	32·4	34·0	32·7	38	32	0·6	5·2	1·3	·18	·14	·17	94	68	86	NW 3	NW 3	NNW 3
49·6	29·172	49·8	29·108	52·0	29·004	9	30·26	30·18	30·07	32·6	31·2	38·4	37·9	39·2	38·8	40	26	1·4	0·5	0·4	·15	·22	·23	84	96	96	NNW 1	WSW 1	WSW 1
53·2	28·842	53·2	28·776	54·4	28·626	10	29·89	29·82	29·65	41·6	40·1	42·7	41·2	44·4	44·0	45	38	1·5	1·5	0·4	·23	·24	·28	89	88	97	W 2	W 2	W 2
52·5	·564	52·8	·456	53·2	·436	11	·60	·49	·47	40·2	39·1	43·0	40·2	40·2	39·1	45	38	1·1	2·8	1·1	·23	·22	·23	91	79	91	WSW 2	W 5	W 6
50·8	·574	50·1	·672	51·8	·760	12	·63	·74	·83	33·3	32·1	35·4	33·8	33·6	32·3	41	33	1·2	1·6	1·3	·17	·17	·17	87	86	86	W 3	W 4	Calm 0
48·6	·504	48·0	·174	51·3	28·106	13	·57	·26	29·14	34·0	33·6	38·1	37·4	36·3	35·6	39	29	0·4	0·7	0·7	·19	·22	·20	96	94	94	SW 1	SW 2	WSW 7
49·2	·238	50·0	·292	52·5	27·964	14	·29	·33	28·98	37·3	35·7	38·8	36·4	41·1	40·6	41	34	1·6	2·4	0·5	·19	·20	·25	87	81	96	WSW 6	WSW 3	WSW 5
50·5	·196	50·6	·272	50·5	28·258	15	·25	·32	29·31	33·0	30·9	37·3	33·7	33·6	32·8	43	32	2·1	3·6	0·8	·15	·16	·18	77	71	91	W 2	WSW 4	SSW 3
49·6	·356	49·0	·506	50·3	·704	16	29·42	·57	·78	31·5	29·2	33·0	31·3	32·1	30·9	34	29	2·3	1·7	1·2	·13	·15	·15	71	81	85	SW 2	WSW 3	WSW 3
50·1	·960	50·0	·860	53·0	·834	17	30·03	·92	·87	35·6	34·7	38·5	37·0	45·6	43·2	46	30	0·9	1·5	2·4	·19	·20	·25	92	87	82	SW 4	SW 5	SW 8
51·3	28·746	51·8	28·692	54·2	28·705	18	29·79	29·73	29·74	44·1	42·3	45·1	42·8	45·0	43·2	46	43	1·8	2·3	1·8	·25	·25	·26	85	83	86	SW 7	SSW 5	SSW 6
52·0	29·000	51·0	29·094	52·7	29·200	19	30·07	30·17	30·27	35·3	34·5	38·4	35·3	35·2	33·8	46	33	0·8	3·1	1·4	·19	·17	·18	93	75	87	WNW 1	WNW 1	WNW 1
50·0	·416	51·4	·456	53·3	·508	20	·50	·54	·60	36·6	34·0	40·0	35·9	33·5	32·5	42	33	2·6	4·1	1·0	·17	·17	·17	78	68	89	Calm 0	WNW 1	Calm 0
47·2	·472	49·2	·416	51·4	·412	21	·60	·51	·53	25·2	24·5	33·7	32·2	24·4	24·0	34	24	0·7	1·5	0·4	·11	·16	·12	83	84	90	Calm 0	S 1	Calm 0
47·6	·332	48·4	·286	51·0	·265	22	·45	·38	·36	25·2	24·7	34·2	32·7	32·1	31·5	34	21	0·5	1·5	0·6	·12	·17	·17	88	84	92	Calm 0	Calm 0	Calm 0
50·0	·182	48·5	·108	50·8	·090	23	·28	·20	·18	31·2	30·4	32·9	31·6	29·0	27·9	33	29	0·8	1·3	1·1	·16	·16	·13	88	85	81	E 2	E 2	E 1
48·9	·076	48·7	·098	49·5	·200	24	·18	·19	·31	27·6	26·8	29·6	28·5	26·2	25·0	30	25	0·8	1·1	1·2	·13	·13	·10	84	82	73	SSE 1	SSE 1	Calm 0
41·8	·293	46·4	·307	48·1	·408	25	·44	·40	·54	17·0	15·9	35·6	32·2	20·5	20·0	36	16	1·1	3·4	0·5	·06	·15	·09	65	70	85	Calm 0	SW 1	Calm 0
45·3	·434	47·2	·424	48·6	·482	26	·56	·52	·62	21·3	20·7	37·1	34·7	21·2	20·8	37	16	0·6	2·4	0·4	·09	·18	·10	82	80	88	Calm 0	Calm 0	Calm 0
45·3	·454	46·8	·407	47·8	·404	27	·59	·52	·54	23·2	22·8	31·0	28·8	19·3	18·9	31	17	0·4	2·2	0·4	·11	·12	·09	89	70	88	Calm 0	Calm	Calm 0
44·5	·308	46·8	·230	49·5	29·188	28	·44	·32	·28	23·6	22·8	38·0	34·4	31·1	29·7	41	13	0 8	3·6	1·4	·10	·16	·14	79	71	80	SSW 1	SSW 2	SW 1
46·8	·098	47·8	·082	50·4	28·994	29	·19	·16	·06	35·3	35·0	38·2	37·0	37·2	36·0	40	31	0·3	1·2	1·2	·20	·21	·20	97	90	89	WSW 1	W 3	WNW 5
48·7	29·088	49·9	29·098	48·8	29·090	30	·18	·17	30·18	30·5	28·0	36·5	32·2	30·2	29·6	37	27	2·5	4·3	0·6	·11	·14	·15	66	65	90	N 2	NNW 3	NW 1
46·8	28·994	47·0	28·936	50·2	28·894	31	30·09	30·02	29·97	30·0	29·2	33·1	32·7	35·2	34·6	37	29	0·8	0·4	0·6	·15	·18	·19	86	95	94	NW 2	NW 2	NW 1
307·0	2·541	6·9	1·700	60·8	1·589	Sums	5·12	3·94	3·87	115·1	78·7	256·2	191·9	150·8	120·6	10	14	36·4	64·3	30·2	5·39	6·01	5·80	181	66	273	— 52	— 66	— 68
49·9	29·082	50·2	29·055	52·0	29·051	Means	30·165	30·127	30·125	33·7	32·5	38·3	36·2	34·9	33·9	40·3	30·5	1·2	2·1	1·0	·173	·194	·187	86	82	89	— 1·7	— 2·1	— 2·2
1	2	3	4	5	6		7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

SUMMARIES.

Weather—No. of days of

Rain,	Snow,	Hail,	Thunderstorm,	Clear Sky,	Overcast,	Fog,	Gales,
16	10	5	1	4	13	6	3

Wind—No. of Observations of

Forces 4–7,	Calm,	N,	NE,	E,	SE,	S,	SW,	W,	NW.
17	20	3	0	3	1	6	20	28	12

T BUXTON DURING JANUARY, 1909.

Height above Mean Sea Level of Barometer Cistern, 997 ft.
Height above ground of Thermometers, 4 ft.
Height above ground of rim of Rain Gauge, 1 ft.
Height above Mean Sea Level of Rain Gauge, 988 ft.

Hours of Observation { I. = 9 a.m. = 9h. Local Mean Time. II. = 3 p.m. = 15h. Local Mean Time. III. = 9 p.m. = 21h. Local Mean Time.

Hour of Reading and Setting Max. and Min. Thermometers. } = 21h.

Cloud. Amount. II. 3 p.	Cloud. Amount. III. 9 p.	Cloud. Form. I. 9 a.	Form. II. 3 p.	Form. III. 9 p.	Direction whence coming. I. 9 a.	Direction II. 3 p.	Direction III. 9 p.	Weather at time of observation. I. 9 a.	at time II. 3 p.	at time III. 9 p.	Weather during interval ending at. I. 9 a.	during interval II. 3 p.	during interval III. 9 p.	Rain. Amount during 24 hours beginning 9 a.m.	Rain. Estimated duration.	Depth of Snow at 9 a.m.	Bright Sunshine.	Radiation. Min. on Grass.	Radiation. Max. in Sun. Black Bulb in vacuo.	Earth Tempr. 1 foot.	Earth Tempr. 4 feet.	Symbols	REMARKS.
														ins.	hrs.		hrs.	°	°	°	°		
8	10	—	st-cu	ni	—	SW ?	WSW	f	c f	o m	f e	f, o p	c f, m	·01	¾		—	32	51	36·7	43·8	≡	Damp early a., ≡ most of day.
8	9	ci-cu / st-cu	ci / st-cu	st-cu	? / W	? / W	WNW	c	c	o	om, odm	c	c	—	—		0·8	36	66	37·2	43·7		●° n., cloudy day, bright at intervals. Ѱ
7	9	st-cu	st-cu	st	WNW	WNW	WNW	c	c	c	c	b c, c	c, o m	—	—		2·7	38	63	38·7	43·5		Fair though cloudy till 3 p., overcast later.
10	10	—	—	—	—	—	—	o u	o	o	c, o u	o u, o	o	—	—		—	39	54	39 5	43·5		Threatening early a., very dull day. [Ѱ
3	0	st-cu	cu	—	S	SSE	—	o	b c	b	o	o, b c	b c	—	—		1·2	26	53	40·0	43·5		Dull early a., clearing towards noon, cloudy n. Ѱ
10	10	ci-cu / st-cu	—	—	? / NW	—	—	c	o g	o	b, b c, c	c, o r, o g	o g, o	·12	3¾		—	27	53	39·4	43·4		Fine till 10 a., ● 10.30 a.-1.45 p., gloomy p., [Ѱ
10	10	st-cu	ni	ni	WNW	W	NNW	c	o	o r s	o, o r, c	c, o r, o	o, tlr, h, s	·27	4½		—	32	55	39·2	43·4	▲ ☈ ✱	● n., dull morning, ● 1.30–2.30 p. and 3.45–6.20 p. ☈ ▲ ✱ 6.5-6.20 p. ● ✱ 8.20-9.30 p.
2	7	cu	cu	st-cu	NW	NNW	NNE	c	b c	c	o r s, o	c, b c	b c, o	—	—		3·7	28	64	38·8	43·5	✱	Very nice day, ✱ 6.45-7 p.
10	10	st-cu	—	—	NNW	—	—	c	m	f	c, b c, c	c, o m	o d m	·26	2½		—	19	61	38·0	43·4	≡	Nice early a., becoming warmer, damp, misty p.
7	10	a-st., ni	st-cu	—	W	W	—	c	c	o r	m, o r, c	c	c, o r	·08	3		—	37	55	38·0	43·3		● n., fine day but cloudy, ● 6.10–8.30 p.
3	5	ci., ci-cu / st-cu	ci / st-cu	—	W / WSW	? / WNW	W	c	b c	b c	o p, c	c, b c	b c, c d, l e	·24	1½		3·7	35	65	39·0	43·3		● n., very nice till evening, ● (d) 7–8 p.
7	0	cu	st-cu	—	WNW	WNW	—	b c	c	b	b c, h, o	c p s	c p s, b c	·02	1		0·7	26	60	39·1	43·3	▲ ✱	▲ n., ✱ p. during day, starlight night.
10	10	—	ni	ni	—	SW	W	o s	o r	o r	b, c, o s	o r, o, o r	o r	·40	5		—	24	54	38·3	43·2	✱	✱ 8.45-11.30 a. (showers). ● (showers) p. and n.
10	10	st-cu	—	—	W	—	—	c	o	o r	h r s p	c, o	o, o r	·45	5½		—	33	56	37·8	43·0	✱ ⟋ ▲	⟋ with ● ▲ ✱ n., dull morning.
0	8	—	—	cu-ni	—	—	SW	b	b	c	r h p, b	b	b, c	·24	1¾		5·0	28	82	37·9	42·9	▲² ✱	●² ▲² (showers) n., beautiful till 3 p., ✱ 9.15–10.40 p.
8	7	st-cu	ci-st	cu	?	W	WSW	b	c	c	s, b c	b, o s	c	·05	1		1·5	26	80	37·4	42·9	✱	✱ n., $\boxed{✱}$ 2″, fine a., ✱ 12.15-12.55 p., dull p.
10	3	cu-ni	ni	cu	SW	SW	SW	o	o	b c	c, b, s p	o	o, b c	·01	¼		—	28	56	37·0	42·9	✱ ⟋	✱ n., dull day, ⟋ n.
8	8	cu	st-cu	st-cu	WSW	SSW	SSW	c	c	c	b c, o d	c, b c, c	c	·16	2½		0·5	33	63	37·9	42·8	⟋	⟋ n., ●° 8.30–8.45 a., cloudy day, ● 9.15 p.
1	2	st-cu	cu	cu	WNW	WNW	WNW	c	b	b c	o r, c	c, b	b c	·01	¼		3·2	28	58	38·9	42·7		● n., cloudy a., fine p. ●° 9.30–9.50 p.
0	2	—	—	ci-cu	—	—	?	b	b	b c	d, b	b	b c	—	—		5·4	25	70	38·3	42·7		⌴ n., magnificent day.
0	10	—	—	—	—	—	—	b m	b	f	b, b c	b	b, f	—	—		4·8	20	63	37·5	42·7	≡	⌴ a., beautiful till 3.30 p. ≡ n.
7	10	ci., cu, st	ci / st-cu	—	E	NE / E	—	m	c	o	f, b	f, c	c, o	—	—		0·5	20	58	36·5	42·5	≡	≡ till 10 a., cloudy with bright intervals.
9	7	—	st-cu	?	—	ESE	?	o	c	c	o	o, c	c	—	—		—	23	50	36·2	42·6		Dull cold day.
10	10	—	—	—	—	—	—	o	o	o	c, b c	o, s, o	o	trace	¾		—	16	51	35·7	42·5	✱	Very dull all day, ✱° 10.15–11 a.
0	0	—	—	—	—	—	—	b m	b	b m	f b	m, b	b, m	—	—		3·1	14	71	35·5	42·4		⌴, mist till 10 a., very fine day, misty n.
0	0	—	—	—	—	—	—	b	b	b	b m	b	b	—	—		5·0	13	73	35·0	42·2		⌴² n, magnificent day.
0	0	—	—	—	—	—	—	f²	b	b	b, f	f, b	b	—	—		5·4	11	61	34·8	42·0	≡	V n., ≡² till 10.30 a., ≡ till noon, splendid p.
8	2	st-cu	ci-st	ci	?	?	—	b	c	b c	b, f, b	b, c	c, b c	—	—		3·4	9	84	34·5	41·8	≡	V and ≡ n., fine a., cloudy p.
8	10	—	cu., st-cu	—	—	WNW	—	o	c	o	b c, o	b c, c	c, o	·04	¾		1·3	23	69	34·4	41·7		Cloudy day with bright intervals, dull n.
0	0	cu	—	—	N	—	—	b c	b	b	r h p, b c	b c, b	b, b c	—	—		6·0	21	75	34·4	41·4	▲	▲ ● showers n., beautiful day.
10	10	st-cu	—	—	NW	—	—	c	o s	o r	b, c	c, o s	o s, o r, o	·18	5½		0·1	21	54	34·2	41·1	✱	Cloudy a., ✱ 2–4 p., ● ✱ 4–4.45 p., ● 9–9.30 p. and n.
184	199	—	—	—	—	—	—	—	—	—	—	—	—	2·54	40		58·0	—	—	225·8	87·6	—	

WEATHER DIARY.*

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* This is intended to be a short record of the weather for each day such as the observer might give if asked to describe it at the close of the day. Examples are given in the Observer's Handbook, § 8, 1911 Edition. An additional example is appended here.

1 Early morning overcast and dark: rain in isolated drops about 9h. gradually increased to a steady downpour by 10h. which continued to 15h. when it began to clear. Wind changed rather rapidly about this time from SW to WNW, gradually falling off. Clear night, beginning to freeze on the ground.

PHENOLOGICAL INFORMATION—DATES OF.

Name of Previous Year's Crop.	Crops.	Sowing or Planting.	Appearing above Ground.	In Ear or Flower.	Cut or Raised.	Character of Crop.
	Barley					
	Beans					
	Oats					
	Peas					
	Rye					
	Wheat					
	Potatoes					
	Mangold					
	Turnips					
	Clover					
	Meadow Grass					

Forest Trees.	In Flower.	Leaf Buds Appear.	In Leaf.	Leaves Fallen.	Shrubs and Fruit Trees.	In Blossom.	Fruit Ripe Generally.
Alder					Elder		
Ash					Hawthorn		
Beech					Mountain Ash		
Birch					Apple		
Elm					Cherry		
Larch					Pear		
Lime					Plum		
Oak					Black Currant		
					Gooseberry		

In estimating Character of Crop the following scale should be used. 1 Bad. 2 Indifferent. 3 Fair. 4 Good. 5 Very Good. 6 "Bumper."

APPENDIX II.

Instructions for Observers sending Evening Reports for Circulation to Newspapers and News Agencies.

Arrangements have been made by the Meteorological Office for the issue to the Press of a daily report embodying the information received by telegraph from health resorts. The observations included in these schedules comprise the amount of bright sunshine and the maximum temperature for the day, the minimum temperature and the amount of rainfall for the 24 hours ended at 6 p.m., and, further, the observations of the barometer, wind, temperature and weather recorded at 6 p.m. This statistical information is supplemented by brief notes regarding the general character of the weather or any exceptional phenomena such as thunderstorms, unusually heavy rainfall, &c.

Observations of Maximum and Minimum Temperature and of Rainfall.

Monthly means of maximum and minimum temperature for the 24 hours ending at 6 p.m. and measurements of rainfall referring to this period are not suitable for climatological comparisons and are, therefore, not published in the Monthly Weather Report. The rainfall data published in that report refer to observations made at the hour of morning observation, and the maximum and minimum temperatures refer to the 24 hours ended at (7 a.m.) 9 a.m. or 9 p.m. In order to meet the requirements of the newspapers, special observations must be made at 6 p.m. at those stations which contribute evening reports by telegram, but the observations of maximum and minimum temperature and of rainfall incorporated in the telegrams cannot be used in the Monthly Weather Report. In order to avoid confusion the particulars required for the two sets of reports are set out here. It is highly desirable to provide two raingauges for the two independent sets of observations, and also to provide a second minimum thermometer at auxiliary climatological stations where readings are taken at 9 a.m. and 6 p.m. and a second maximum thermometer at normal climatological stations where an observation is also made at 9 p.m. The additional thermometers can be accommodated in the screen without difficulty.

Evening Reports by Telegraph.

The maximum temperature reported by telegram *must* be for the period from the morning observation 9 a.m. (or 7 a.m.) up to 6 p.m.

The minimum temperature *must* be for the 24 hours from 6 p.m. the previous evening to the time of telegraphing (or for the 21 hours from 9 p.m. the previous evening).

The rainfall *must* be for the 24 hours from 6 p.m. the previous evening.

The sunshine must be the duration from sunrise to 6 p.m. It must *not* be for the 24 hours 6 p.m. to 6 p.m.

Reports for Monthly Climatological Returns.

(1) *Auxiliary Climatological Stations. Observations at 9 a.m. and 6 p.m.*

The maximum temperature must be for the 24 hours 9 a.m. to 9 a.m. It should be entered to the day previous to that on which the reading is taken.

The minimum temperature must be for the 24 hours 9 a.m. to 9 a.m. It should be entered to the day on which the reading is taken.

The rainfall must be for the 24 hours 9 a.m. to 9 a.m. It should be entered *invariably* to the day previous to that on which it is measured *even if* the observer knows that it all fell in the morning of the day of observation.

The sunshine must be that for the whole day from sunrise to sunset. The cards should be changed after sunset when no difficulty arises.

Procedure at Auxiliary Climatological Stations.—The requirements for maximum temperature are fulfilled if the thermometer is read *and set in the morning* and read, *but not set* at 6 p.m.

For minimum temperature and rainfall the simplest method of carrying out the above arrangements is to have two minimum thermometers and two raingauges, and use one set for the monthly returns and the other set for the telegraphic reports.

If duplicate instruments cannot be provided the following procedure may be followed :—

Minimum Thermometer.—*Read and set* the instrument *both* in the morning *and* at 6 p.m. Enter the readings in the pocket register as they are taken, and use the lower of the last two entries in the book for telegraphing or for the monthly return.

Thus, if consecutive readings are as follows :

		9 a.m.		6 p.m.
July 9	... ...	56°	...	54°
„ 10	... ...	50°	...	55°
„ 11	... ...	57°	...	61°

the reading telegraphed at 6 p.m. on the 9th will be 54°, the lower of the two readings 56° and 54°. On the 10th it will be 50°, the lower of the two readings 50° and 55°. On the 11th it will be 57°.

The reading entered in the monthly returns to the 10th will be 50°, the lower of the readings 50° and 54°. On the 11th it will be 55°, the lower of the two readings 57° and 55° although the reading 55° actually occurred on the 10th.

Raingauge.—Measure the amount both at 9 a.m. and at 6 p.m. and pour it away on each occasion. The amount telegraphed should be the sum of the last two measurements. The amount entered in the monthly return should be the sum of the measurement at 6 p.m. and at 9 a.m. the next day.

Thus, if consecutive measurements are as follows :

		9 a.m.		6 p.m.
June 5	... ...	0·05 in.	...	0·21 in.
„ 6	... ...	0·13	...	0·00
„ 7	... ...	0·02	...	—

the amount telegraphed at 6 p.m. on June 5th should be 0·26, *i.e.*, 0·21 + 0·05. The amount telegraphed on June 6th should be 0·13, *i.e.*, 0·00 + 0·13.

The amount entered in the monthly return to June 5th should be 0·34, *i.e.*, 0·21 + 0·13 ; and to June 6th should be 0·02, *i.e.*, 0·00 + 0·02.

(2) *Normal Climatological Stations. Observations at 9 a.m., 9 p.m., and 6 p.m.*

The rainfall is measured at 9 a.m., and the instructions given above with reference to rainfall apply ; but it is especially desirable at these stations that two raingauges should be used.

The minimum thermometer should be set at 9 p.m. and read, but not set at 6 p.m. The reading entered in the monthly report should be that taken at 9 p.m. The minimum temperature reported by telegram should be for the 21 hours 9 p.m. to 6 p.m.

The maximum temperature entered in the monthly report should be that read at 9 p.m. and a second maximum thermometer should be provided and should be set at 9 a.m. and read at 6 p.m.

If a second instrument cannot be provided the maximum thermometer should be read and set at 9 a.m. and 9 p.m. and read, but not set at 6 p.m. The reading telegraphed should be that taken at 6 p.m. The reading entered in the weekly or monthly return should be the higher of the two readings taken at 9 a.m. and 9 p.m.

Thus, if readings were :

	9 a.m.	6 p.m.	9 p.m.
July 21	56° ...	65° ...	65°
„ 22	62° ...	57° ...	58°

The readings telegraphed would be 65° on the 21st and 57° on the 22nd. The readings entered in the monthly return would be 65° on the 21st, *i.e.*, the higher of 65° and 56° ; and 62° on the 22nd, *i.e.*, the higher of 58° and 62°.

TELEGRAPHIC CODES FOR USE BY OBSERVERS AT HEALTH RESORTS.

All messages should be addressed " Weather Southkens London."

The message should consist of 4 groups of 5 figures each—counting as 4 words. Whenever it is impossible to supply any portion of the information the vacant space should be filled in with ciphers, so as to keep the group intact.

Composition of Groups.

First Group.—*Barometer reading* at 6 p.m. corrected for temperature and reduced to sea-level (three figures) ; and *Direction of Wind*, as per accompanying scale (two figures)—

Scale for Wind Direction.

N.	=	32	S.S.W.	=	18
N.N.E.	=	02	S.W.	=	20
N.E.	=	04	W.S.W.	=	22
E.N.E.	=	06	W.	=	24
E.	=	08	W.N.W.	=	26
E.S.E.	=	10	N.W.	=	28
S.E.	=	12	N.N.W.	=	30
S.S.E.	=	14	N	=	32
S.	=	16	Calm.	=	00

Specimens of Group :—

(*a*) 99604 = *Barometer reading* 29·96 inches (the first figure always omitted) ; *Wind Direction* N.E.

(*b*) 00122 = *Barometer reading* 30·01 inches ; *Wind Direction* W.S.W.

Second Group.—*Force of Wind*, by Beaufort Scale (two figures); *Weather at 6 p.m.*, by weather scale given below (one figure); *Dry Bulb temperature at 6 p.m.* (two figures).

Beaufort Scale for Wind Force.

Calm	= 00	High wind	= 07
Light air	= 01	Fresh gale	= 08
Light breeze	= 02	Strong gale	= 09
Gentle breeze	= 03	Whole gale	= 10
Moderate breeze	= 04	Storm	= 11
Fresh breeze	= 05	Hurricane	= 12
Strong breeze	= 06		

Scale for Weather.

0 = Sky quite clear.	5 = Rain falling.
1 = Sky a quarter clouded.	6 = Snow falling.
2 = Sky half clouded.	7 = Mist or haze.
3 = Sky three quarters clouded.	8 = Fog.
4 = Sky entirely overcast	9 = Thunderstorm.

Specimens of group:—

(*a*) 02360 = *Force of Wind* 2 (a light breeze); *Weather*, Sky three-quarters clouded; *Dry Bulb temperature* 60°.

(*b*) 10549 = *Force of Wind* 10 (a whole gale); *Weather*, Rain falling; *Dry Bulb temperature* 49°.

Third Group.—*Maximum temperature for day* (two figures); and *Amount of Bright Sunshine for day, up to 6 p.m.*, in hours and tenths of hours (three figures)—

Specimens of group:—

(*a*) 48032 = *Maximum temperatare* 48°; *Amount of Bright Sunshine* 3·2 hours.

(*b*) 69118 = *Maximum temperature* 69°; *Amount of Bright Sunshine* 11·8 hours.

(*c*) 40000 = *Maximum temperature* 40°; *Amount of Bright Sunshine* Nil.

Fourth Group.—*Minimum temperature for 24 hours ending with 6 p.m.* (two figures), and *Amount of Rainfall* for same period (three figures)—

Specimens of group:—

(*a*) 38024 = *Minimum temperature* 38°; *Rainfall* 0·24 inch.

(*b*) 42102 = *Minimum temperature* 42°; *Rainfall* 1·02 inch.

(*c*) 35005 = *Minimum temperature* 35°; *Rainfall* 0·05 inch.

Additional Notes.

Brief notes should be added reporting the general character of the weather during the day, and drawing attention to unusual occurrences such as thunderstorms, hailstorms, &c. This information may be conveyed by combining the letters given below into groups *of not more than five letters.* Such a group counts

as one word in a Post Office telegram. It will be convenient to use one group of letters to indicate the weather of the forenoon and a second group that of the afternoon. These two groups of letters should be placed before the four groups of figures referred to above. If a single letter is sufficient to characterise the weather of forenoon or afternoon, it is advisable to write out the word for which it stands in full, to avoid errors in transmission.

We give a few examples :—

bcodm rbcph

Forenoon : fine early (bc) becoming dull (o) with drizzle (d) and (mist).

Afternoon : raining at first, fair intervals, some showers with hail later.

---

cvtlr dull

Forenoon : cloudy with unusual transparency early (cv) thunderstorm with rain later (tlr).

Afternoon : dull throughout.

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fc brg

Forenoon : foggy early, then becoming cloudy.

Afternoon : fine at first, becoming rainy and gloomy.

A complete message might read as follows :—

Weather, Southkens, London.

fc brg 97822 03452 56032 42013

Address and text amount together to eight words. The remaining four words which can be included in a sixpenny telegram may be used at discretion for additional remarks such as "much rain last night," "pleasant breeze," or "barometer rising."

APPENDIX III.

The Publication of Meteorological Data for the British Isles.

The results of observations made in accordance with the rules given in the preceding pages are contained in the following publications which are issued by the institutions whose names appear on the title page :—

Meteorological Office.—The British Meteorological and Magnetic Year Book. Part I. Weekly Weather Report, with appendices. Issued on Thursday of each week. Price 6*d.* per number. Annual subscription (which includes the Monthly Weather Report) 30*s.*, postage paid.

Part II. The Monthly Weather Report, with an annual summary. Issued as a supplement to the Weekly Weather Report on the 27th day of each month. Price 6*d.* per number.

Part III. (1.) Daily Readings at Stations of the First and Second Orders. Issued in Monthly Parts within about five weeks of the close of each month. Price 6*d.* each part. Annual volume, with title page and introduction. (2.) The Geophysical Journal of the Observatories of the Meteorological Office. Issued in monthly parts. Price 1*s.* each part.

Part IV. (1.) Hourly Values from autographic records —Meteorological Section. Obtained from self-recording instruments at three observatories. Issued in monthly parts for each observatory within about six weeks of the close of each month. Price 6*d.* each part. Annual volume, with title page and introduction, and summary for five observatories. (2.) Hourly Values from autographic records —Geophysical Section, published with an introduction and summary at the end of each year. Price 5*s.*

Parts I. and II. can be purchased directly or through any Bookseller from Wyman and Sons, Ltd., Fetter Lane, E.C. ; H.M. Stationery Office (Scottish Branch), 23, Forth Street, Edinburgh, or E. Ponsonby, Dublin. Parts III. and IV. are on sale at the Meteorological Office only.

The Daily Weather Report.—Issued daily (Sundays and Bank Holidays excepted) at 1 p.m. Subscription (to cover cost of postage and wrappers), 5*s.* per quarter ending at the official quarter days, March 31st, June 30th, &c. Single copies 1*d.* each.

The Scottish Meteorological Society. — The Journal of the Scottish Meteorological Society. Issued in annual volumes. William Blackwood and Sons, Edinburgh. The results for normal climatological stations contained in the Journal are printed also in the Quarterly Reports of the Registrar-General of Births, Deaths and Marriages for Scotland.

The British Rainfall Organization. — British Rainfall. Issued in annual volumes. Price 10*s.* each. Symons's Meteorological Magazine. Monthly, price 4*d.* Edward Stanford, Ltd., London.

APPENDIX IV.

Arrangements for the supply of copies of the Daily Weather Report for use in Schools, and other Educational provisions.

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1. *Supply of the Daily Weather Report.*

The Daily Weather Report is a lithograph of four pages in quarto. The information includes, on page 1, a transcript of the observations received at the Office by telegraph from 30 stations in the United Kingdom, 40 stations on the Continent of Europe, Iceland, or the Azores; on pages 2 and 3, maps of Western Europe and the Atlantic Ocean as far as nearly 40° W. longitude, with notes and forecasts based upon the observations; and on page 4, observations received by post or telegraph from about 50 additional stations in the United Kingdom; observations in greater detail from stations in or around London; and finally, the observations received by radio-telegraphy from ships of His Majesty's Navy or Atlantic liners within the 24 hours ending at 9 a.m. The groundwork of the chart for the day printed in blue tints shows the normal distribution of temperature of the surface water of the sea for the month.

The use of the Daily Weather Report for educational purposes is illustrated in Messrs. Simmons and Richardson's Practical Geography (Section III.: Climate), and has been the subject of discussion at various meetings of teachers.

The daily issue is made up for posting at the General Post Office at 1.30 p.m. to addresses which can be reached the same day.

The Report is produced at the public expense. A copy is sent daily to any address upon prepayment of a subscription calculated to cover the costs of transmission at the following rates:—

For an official quarter, beginning January 1st, April 1st, July 1st, or October 1st	5*s*.
For each additional month less than a whole quarter	2*s*.
For additional days beyond an even quarter or month	1*d*. per day.

2. *Supply of Additional Copies of the Daily Weather Report for class use.*

For class use a supply of copies for any particular day or succession of days can be specially printed if notice of the number required reach the office not later than first post on the day of issue. The copies can be printed in the usual way, or the pages of data (pages 1 and 4) can be printed separately from the pages of maps

and remarks (pages 2 and 3), so that the data may be kept separate from the charted results. The charge for these copies is at the rate of 7*d.* for 10 sheets, postage extra.

3. *Presentation of Surplus Copies of the Daily Weather Report and of "Door-board" Charts.*

The Director of the Office is usually able to make up sets of surplus copies of back numbers of the Daily Weather Report, five of each for a consecutive period of about fourteen days, for class use, or to make a similar grant for purposes of examination. He has also for disposal the manuscript charts prepared daily, morning and evening, for exhibition at the Meteorological Office or in St. James's Park. A parcel of one month's charts can generally be sent in reply to requests from schools. In these cases of presentation postage alone is charged.

4. *Other Meteorological Data for Plotting on Charts and Diagrams.*

Other data for the construction of synoptic charts, charts of average values of the various meteorological elements, or isopleths of various elements, and other exercises in meteorology for educational purposes, are contained in the various parts of the British Meteorological and Magnetic Year Book, which comprises :—

Part I. :	Weekly Weather Report 6*d.* per copy, and appendices 4*d.* to 1*s.*	Subscription £1 10*s.* per annum, including postage.
Part II. :	Monthly and Annual summaries 6*d.* per copy.	
Part III. :	*(1) Daily Readings at 8 stations of the First and Second Orders.	6*d.* per issue of a month.
	*(2) Geophysical Journal, comprising daily values of meteorological and magnetical data for the three Meteorological Office Observatories—Valencia, Kew, and Eskdalemuir ; Electrical data for Kew and Eskdalemuir ; Seismological data for Eskdalemuir ; wind components for Holyhead, Scilly, Orkney, and Yarmouth, and observations in the upper air.	1*s.* per issue of a month.
Part IV. :	*(1) Hourly values from autographic records ; Meteorological Section : Hourly values of the meteorological elements at the three Meteorological Office Observatories —Valencia, Kew, and Eskdalemuir	6*d.* per issue of a month for each Observatory.

* The data of these sections are expressed in Centimetre-Gramme-Second units.

*(2) *Hourly values from autographic records; Geophysical Section:* Hourly Readings of Terrestrial Magnetic Force at Eskdalemuir; with diurnal inequalities for terrestrial magnetism and atmospheric potential gradient, and monthly and annual summaries of hourly values of meteorological and geophysical data at the Meteorological Office Observatories.	Annual issue. Price 5*s*.

No systematic issue of data for the whole British Empire is yet arranged, but the greater Colonies and Dependencies issue monthly reports, which can be used in the same way as the British Meteorological and Magnetic Year Book.

5. *Marine Charts.*

Monthly Meteorological Charts of the North Atlantic Ocean and Mediterranean, and of the Indian Ocean and Red Sea, are issued monthly, price 6*d*. each, exclusive of postage. They furnish numerous illustrations of the physical geography of these regions of the ocean, and particularly of the monsoon region. Surplus copies of certain of the back numbers of these charts can be supplied on special terms.

6. *Syllabus of Rudimentary Instruction in Weather Study for use in Elementary Schools.*

At the request of a member of Parliament, a syllabus of rudimentary instruction in Weather Study for use in elementary schools has been drawn up, and a typewritten copy can be had on application, price 1*s*. post free.

7. *Books of Instructions and Publications.*

For instruction in the use of Meteorological Instruments "The Observer's Handbook" has been prepared, and is on sale at Messrs. Wyman and Sons, Fetter Lane, London, E.C., or any bookseller, price 3*s*.

"The Barometer Manual for the use of Seamen," price 6*d*., Wyman and Sons, is a compendium of instruction in meteorology for sailors.

"The Fishery Barometer Manual," price 6*d*., Wyman and Sons, is intended for instruction in the practical use of the barometer in fishing villages, &c.

The Seaman's Handbook of Meteorology. [In the Press.]

A list of publications of the Office suitable for more advanced study may be obtained upon application.

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* The data of these sections are expressed in Centimetre-Gramme-Second units.

8. *Lantern Slides.*

In the course of preparation of lectures, papers, and discussions, a considerable collection of lantern slides has been formed, which will be made available, as far as possible, for the use of teachers, either by the loan of a selection of the slides or by the supply of copies of the slides. The charge for the loan of the slides is 2*s*. 6*d*. for a set of not more than 20 slides. Copies of such as can be duplicated will be supplied as a general rule at 1*s*. each. Postage extra in each case.

The slides may be regarded as grouped in relation to the following sections of meteorological work, and a specimen set, generally speaking, of 20 slides, can be made up in illustration of the several subjects enumerated, though they are not to be regarded as giving a full representation of the subjects :—

1. Methods of observation and computation.
    (*a*.) Instruments and records.
    (*b*.) Cloud forms.
    (*c*.) Other Meteorological phenomena.
2. The climatology of the British Isles.
3. The general circulation of the atmosphere and its relation to climate.
4. The climatology of the British Possessions in relation to the general atmospheric circulation.
5. Synoptic weather charts and their use in forecasting.
6. The life history of surface air-currents.
7. The minor fluctuations of the atmosphere and the weather associated with them (Line squalls and thunderstorms).
8. The investigation of the upper air.
9. The meteorology of the sea.
10. The meteorology of the Antarctic.
11. The correlation of meteorological data for different localities—centres of action of the atmosphere.
12. The relation of meteorology to agriculture and hygiene.

A catalogue of the slides in these groups can be obtained on application, price 1*s*.

9. *Photographs of Meteorological Phenomena.*

An Album is kept at the Office for the purpose of preserving the photographs and sketches of Meteorological Phenomena contributed from time to time by the members of the observing staffs of the Office or Observatories.

In the case of negatives belonging to the observers, it has been arranged that copies may be supplied, for personal or class use (but not for reproduction), at a charge of—

9*d*. for a quarter-plate picture, unmounted.
1*s*. „ half-plate „ „
1*s*. 3*d*. „ whole-plate „ „

Copies of the sketches can be obtained by special arrangement.

13th February, 1912.

APPENDIX V.

Instructions for making a Stevenson Thermometer Screen, in accordance with the specification drawn up by a Committee of the Royal Meteorological Society.

Material.—The Screen is to be constructed throughout of the best yellow pine, and all its parts should be put together with tenons, mortices, and brass screws; with the exception of the louvres, which should be fastened together, and secured in their places by brass rivets.

Dimensions.—Its clear *internal* dimensions are to be: length, 18 inches; width, 11 inches; and height, 15 inches.

Framework.—This consists of four corner posts, connected above and below by rails.

The two front posts are to be $1\frac{1}{2}$ inches square, $20\frac{1}{2}$ inches long, and $19\frac{1}{2}$ inches apart; the two back posts are to be $1\frac{1}{2}$ inches square, $19\frac{1}{2}$ inches long, and $19\frac{1}{2}$ inches apart.

The clear distance between the front and back posts must be $12\frac{3}{4}$ inches. The lower rails are all to be $1\frac{1}{2}$ inches square in section, and their under sides must be $1\frac{1}{2}$ inches above the bottom ends of the corner posts. The upper rails are to be $1\frac{1}{2}$ inches wide and 1 inch deep, and the clear space between the upper and lower rails must measure 14 inches.

Louvres.—The Screen must have double louvres, twelve on each face. The outer louvres are to be 2 inches wide, and $\frac{1}{4}$ inch thick; the inner louvres 1 inch wide, and $\frac{1}{4}$ inch thick. The double louvres are formed by nailing the inner louvres to the outer, in the manner indicated in Fig. 1. After they are so fastened the outer louvres are to be slipped into shallow grooves, $\frac{1}{4}$ inch wide and $\frac{1}{8}$ inch deep, cut in the inner sides of the four corner posts of the screen (Fig. 3) at an angle of 45°, and $\frac{1}{2}$ inch apart measured square to the groove (Fig. 2). At the two back inner corners of the Screen the louvres will require to be roughly mitred.

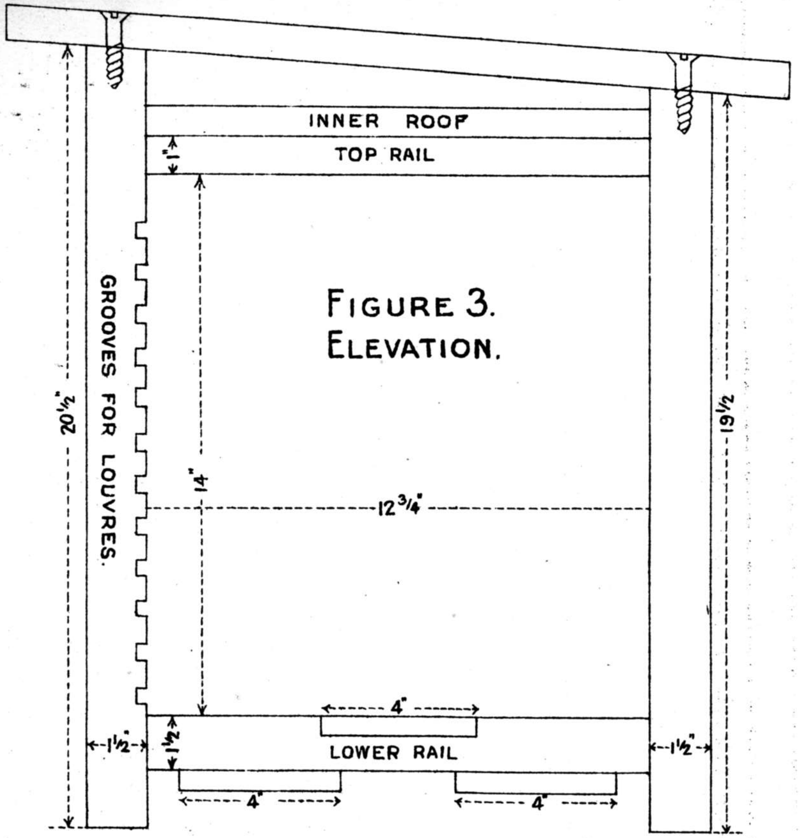


FIGURE 3.
ELEVATION.

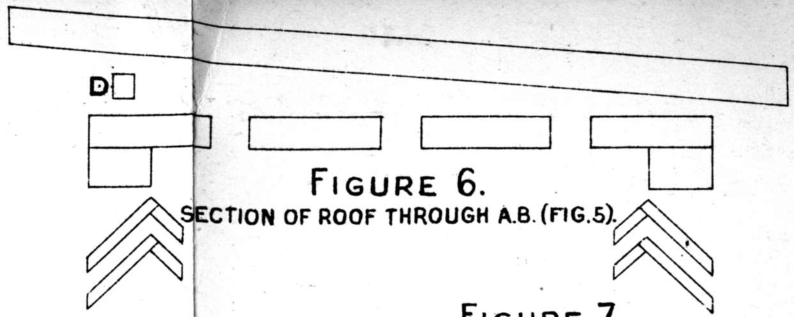


FIGURE 6.
SECTION OF ROOF THROUGH A.B. (FIG. 5).

FIGURE 1.

FIGURE 2.

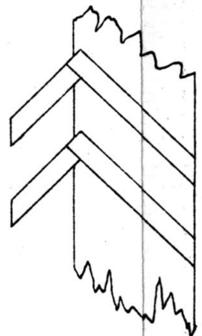


FIGURE 7.

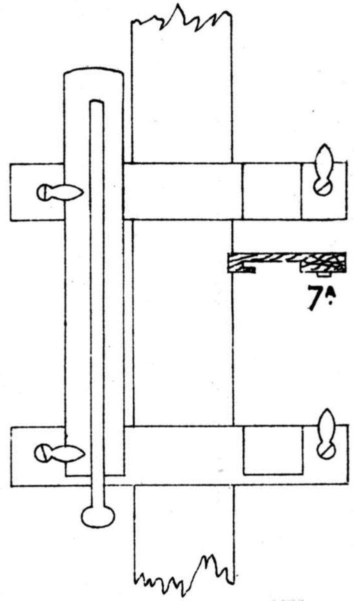


FIGURE 4.

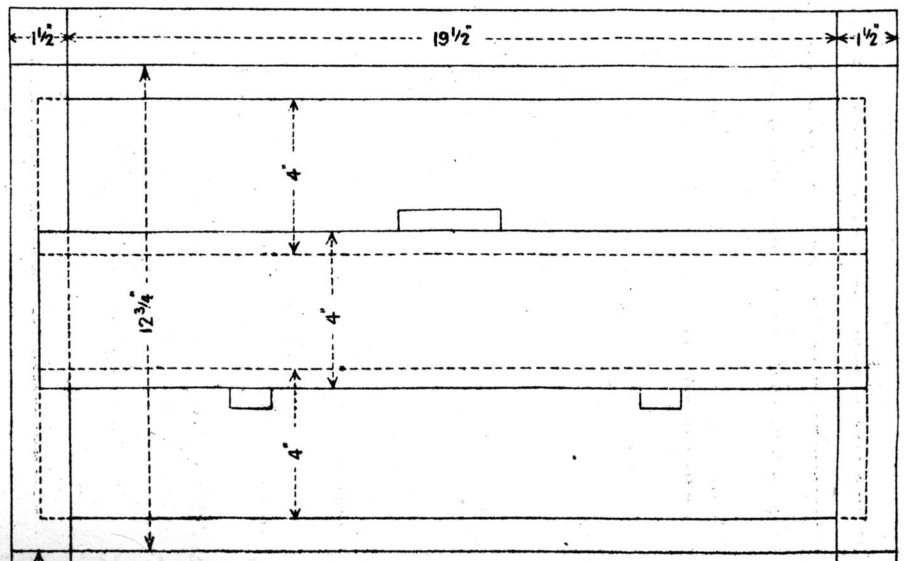


FIGURE 5.

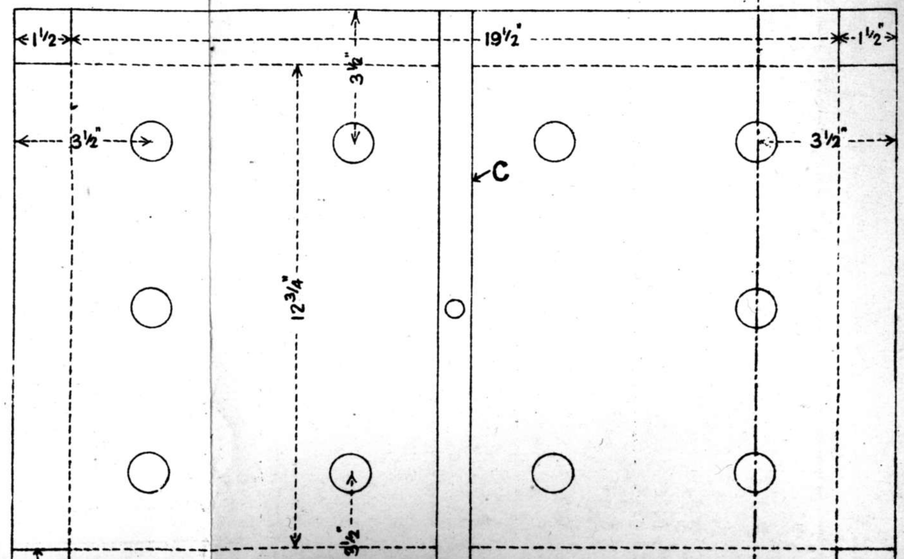


Fig. 8.

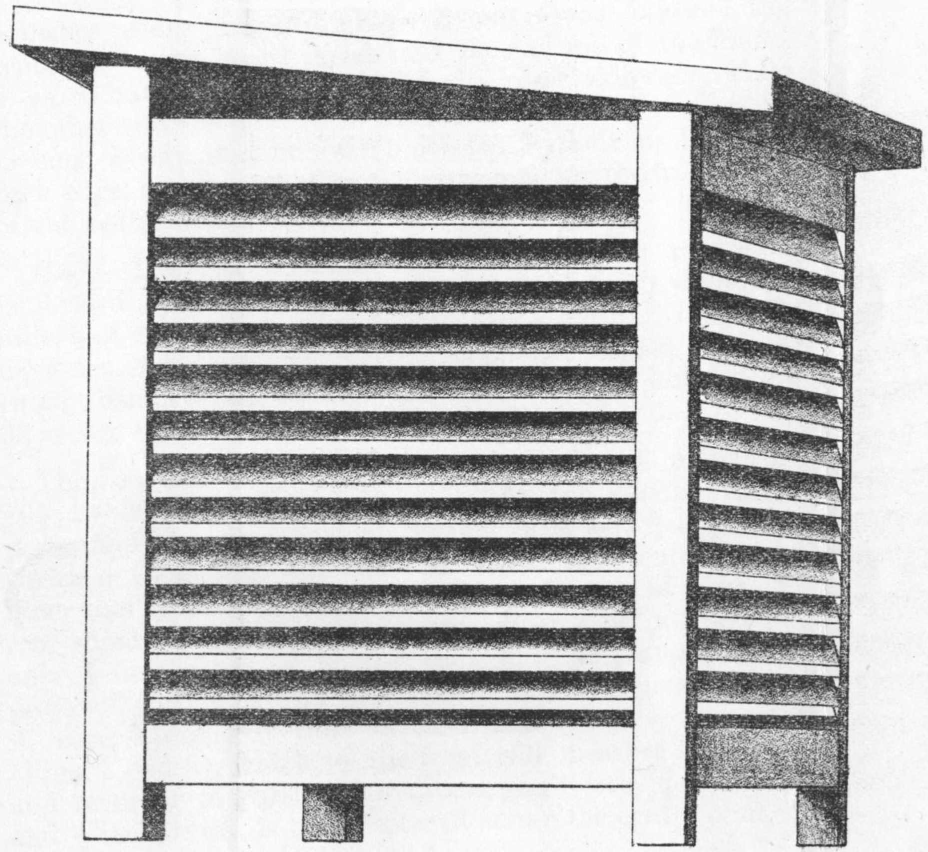
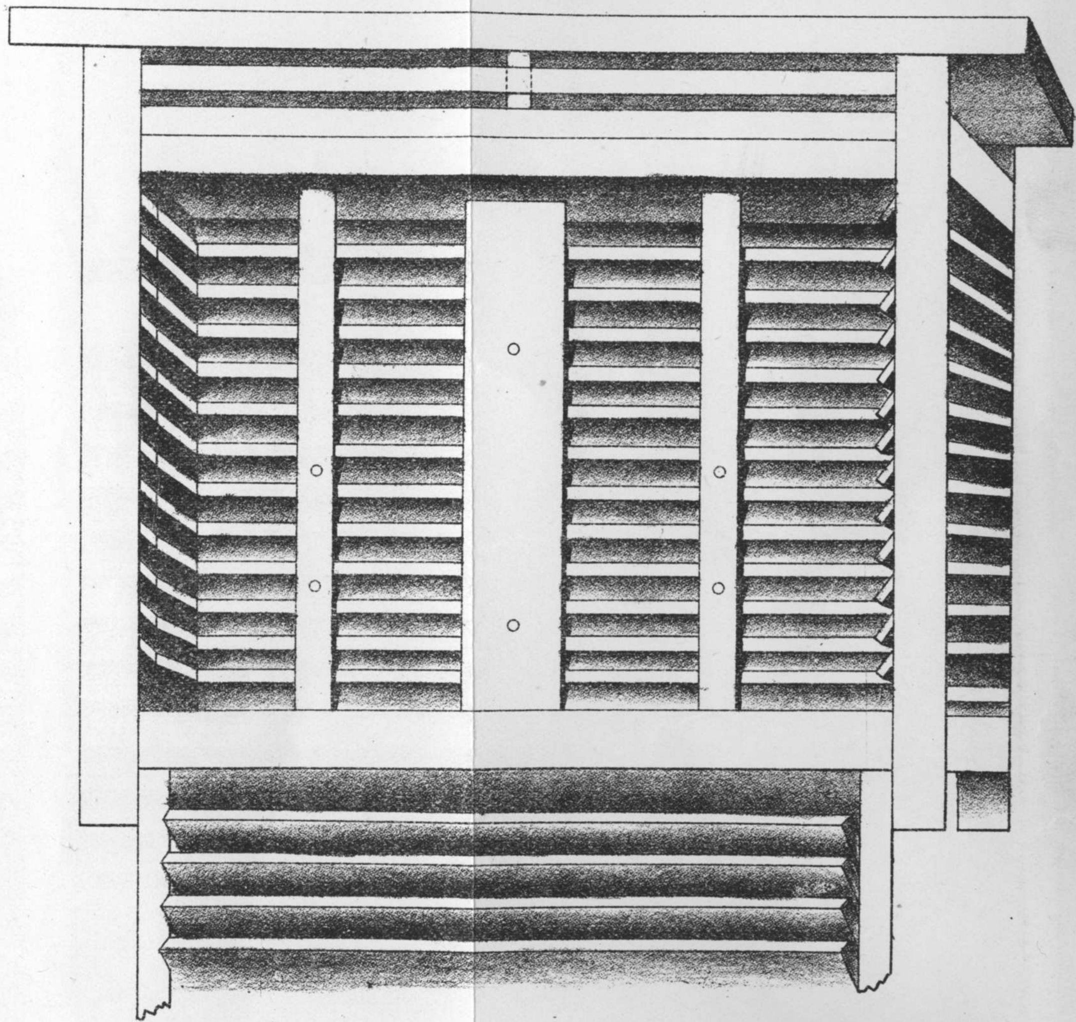


Fig. 9.



Part of Door (open)

The external edges of the outer louvres are to be made flush with the corner posts; the inner louvres will project about $\frac{3}{4}$ inch beyond the posts into the Screen.

Door.—The door forms one of the longer sides of the Screen. It is a rectangular frame of $1\frac{1}{2}$-inches by 1-inch material, fitted with double louvres similar to those described above. It is hung by its outer bottom edge to the lower front rail by two strong brass butt hinges, and closes with its outer surface flush with the corner posts. The door is fastened with a brass hasp and staple, and may be secured by inserting a pin, or by a padlock.

Bottom of Screen.—This is formed by three $\frac{1}{2}$-inch boards, 4 inches wide, arranged (Figs. 3 and 4) as follows: the centre or upper board is let into the end rail of the frame, so as to be flush with the top of the lower side rails, while the other two are screwed to the under sides of the end rails, in such a way that one shall overlap by half an inch the back edge, and the other by the same amount the front edge, of the centre board above.

Roof.—The roof is to be double. The inner roof is to be formed by a board, $\frac{1}{2}$ inch thick, resting upon the upper rails, and cut away to receive the corner posts. It should have ten holes, each an inch in diameter, drilled in it at equal distances all round, the centres of the holes being $3\frac{1}{2}$ inches from the outer edge, as shown in Fig. 5.

The outer roof is to be a 1-inch board measuring $26\frac{1}{2}$ by 20 inches screwed on to the top of the corner posts, and also to a narrow bearing of wood, $\frac{3}{4}$ inch wide (marked C. in Fig. 5), running across the centre of the inner roof from front to back. The under side of the outer roof should be $1\frac{1}{2}$ inches above the inner roof in front, but only $\frac{1}{2}$ inch above it at the back (Fig. 6), and it must project 2 inches beyond the sides of the Screen all round. A clear space will thus be left between the two roofs (Figs. 3 and 6), which in the front will measure $1\frac{1}{2}$ inches, and in order to partly close this a small lath, $\frac{3}{4}$ inch wide and $\frac{1}{2}$ inch thick, is to be fastened across the centre of it, as shown in section at D. in Fig. 6.

Position of Thermometers.—The upright for the Dry and Wet Bulb Thermometers, which should be $2\frac{1}{2}$ inches wide and $\frac{1}{2}$ inch thick, is screwed to the back of the middle bottom board, as shown in Fig. 4, and in Fig. 9. The two uprights across which the Maximum and Minimum

Thermometers are to be hung are screwed to the front of the same bottom board. The upper ends of these uprights are to be screwed to fillets attached to the under side of the inner roof.

If the Dry and Wet Bulb Thermometers are already fixed upon a frame, the frame may be hung upon the upright; but if the Thermometers are separate, two strips of wood should be fixed to the upright, at right angles to it, as shown in Fig. 7. In these cross pieces grooves should be cut, which in the case of the upper one should be right across the strip, but in the lower should stop short of the bottom. These grooves are to be wider at the back than in front, as shown in Fig. 7a. The Thermometer scale is to rest on the bottom of the lower groove, and the instrument is then secured in its place by means of small brass buttons, which are turned over the outside edge of the Thermometer scale, and thus hold it firmly in the groove.

Painting.—Previous to their being put together all the different parts should have two coats of white lead paint; and when completed the whole Screen should receive a finishing coat composed of white zinc paint and copal varnish.

PART IV.

METEOROLOGICAL TABLES.

A. Meteorological Tables for British Units.

B. Conversion Tables between British and Metric Units.

C. Tables for the Correction of Readings of Barometers graduated in Baromils for Temperature and for the Variation of Gravity with Latitude, and their Expression in **Millibars**, and for their Reduction to Mean Sea-level, together with a Table of Saturation Pressures and of Glaisher's Factors.

D. Table for the Conversion of Pressures expressed in British Units to Millibars, and of Temperatures in Degrees Absolute to Degrees Fahrenheit.

Note.—The relation between the inch and the centimetre used in the International Meteorological Tables is 1 in.=2·53995 cm. Since the publication of the International Tables fresh comparisons have been made, and the legalized relation for Great Britain is now 1 in. = 2·54000 cm. This latter has been adopted in the Tables which follow, except Tables IV. and V., which have not been altered.

A. METEOROLOGICAL TABLES FOR BRITISH UNITS.

The Tables published by the International Meteorological Committee, in conformity with resolutions adopted by the International Congress of Meteorologists which assembled in Rome in 1879,* have been used in preparing the tables which follow, wherever possible. The Committee have not issued hygrometric tables, and Glaisher's tables for computing hygrometric values from readings of dry and wet bulb thermometers are accordingly used in all the publications of the Meteorological Office.

Table I.—Reduction of barometric readings to 32° F. (See International Tables Chapter IV., Section II., Table II., pp. 146-175 and also pp. B. 25–30.)

The table is only applicable to mercurial barometers with brass scales extending from the cistern to the top of the mercury. It gives the amount of the correction for every degree from 0° F. to 100°F. and for each half inch of pressure from 26ins. to 31ins. The following is the formula on which it is based :—

$$\text{Correction} = H\frac{\mu\,(t-32)-\lambda\,(t-62)}{1+\mu\,(t-32)}$$

where H is the height of the barometer as read.

t is the temperature of the attached thermometer.

μ is the coefficient of expansion of mercury taken as 0·0001010.

λ is the coefficient of linear expansion of brass taken as 0·0000102.

The temperature used when applying the correction should always be that of the attached thermometer. The correction is zero at 28·5° F. Its amount is to be added to the observed reading at temperatures below 28·5° and subtracted from it at temperatures above this limit.

Table II.—Reduction of barometric readings to mean sea level, (*See* International Tables, Chapter IV., Section II., Table VIII., pp. 32-51, 208–227).

The complete formula for reducing barometric readings to mean sea level is :—

$$Z = 60368{\cdot}6\,[1{\cdot}00157+0{\cdot}002039\,(\theta-32)]\left(1+\frac{Z}{20902950}\right)\left(\frac{1}{1-0{\cdot}378\frac{\phi}{\eta}}\right)(1+0{\cdot}00259\cos 2\lambda)\log.\frac{H_0}{H}$$

where Z = the height of the station in feet above mean sea level.

θ = the mean temperature in degrees Fahrenheit of an air column Z feet in height.

ϕ = the mean pressure of the aqueous vapour in the air column.

η = the mean pressure of the air in the column.

λ = the latitude.

H = the height of the barometer at station level.

H_0 = the height of the barometer at mean sea level.

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* Paris, Gauthier Villars et Fils, 1890.

The term $\left(\frac{1}{1-0{\cdot}378\frac{\phi}{\eta}}\right)$ is the correction for the presence of aqueous vapour in the atmosphere.

The term $(1 + 0{\cdot}00259 \cos 2\lambda)$ is the correction for the variation of gravity with latitude.

At a meeting of Directors of meteorological institutes and observatories held at Innsbruck in 1905, it was agreed that the reduction of barometric readings to mean sea level should be carried out in such a manner that the final results should not differ by more than 0·3 millimetre=0·012 inch from those which would have been given by the above formula,

(1) If the humidity at the time of observing be taken as the mean humidity of the air column, ϕ.

(2) If the mean temperature of the air column be computed from the temperature at the time of observing and a vertical temperature gradient of 0·5°C. per 100 metres or 1°F. per 300 feet.

(3) If we disregard the effect of the variation of gravity with latitude on the correction.

It can be shown* that for altitudes up to 1,000 feet we obtain results usually within the limits of accuracy laid down in the above resolution (1) if we omit the term referring to the humidity, and (2) if we adopt the dry bulb reading at the time of observation for the temperature of the air column and neglect the vertical temperature gradient.

Thus simplified the formula becomes :—

$$Z=60368{\cdot}6\,[1{\cdot}00157+0{\cdot}002039\,(\theta-32)]\left(1+\frac{Z}{20902950}\right)\log\frac{H_0}{H}$$

which may be written

$$\frac{Z}{56525+123{\cdot}1\theta+0{\cdot}003Z}=\log\frac{H_0}{H}$$

$$\text{Let } \log\frac{H_0}{H}=m$$

$$\text{then } (10^m-1)=\frac{H_0-H}{H}$$

$$\text{Again let } (10^m-1)=M$$

$$\text{then } MH=H_0-H$$

H_0-H is the amount which must be added to the observed reading, corrected for temperature, to reduce it to Mean Sea Level.

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* The amount which must be added to a reading of 27 inches at a height of 1,000 feet, assuming a mean temperature of 80° F, and a relative humidity of 75 per cent. is 0·958 inches if the term for the relative humidity be omitted, and 0·948 inches if it be included. Again, the amount to be added to a reading of 30 inches, at a height of 1,000 feet, and a temperature of 0° F is 1·248 inches if we assume the mean temperature of the air column to be 0° F, and 1·243 inches if we adopt a vertical temperature gradient of 1° F per 300 feet. These two cases represent extreme conditions, and for altitudes up to 1,000 feet we shall be usually within the limits of accuracy required by the resolutions adopted at Innsbruck, if we neglect the term in the reduction formula referring to the relative humidity, and assume the dry bulb temperature in the screen as the mean temperature of the air column.

The term $(1+0{\cdot}00259 \cos 2\lambda)$ makes a difference of 0·0012 inches, when applied to the correction for a reading of 30 inches, at an altitude of 1,000 feet, in latitude 65°, and hence it may also be omitted.

The tables published by the International Committee give values of M × 1000, to the nearest 0·1, for increments of altitude of 50 feet and increments of temperature of 5° F. By multiplying these values by H, the observed height of the barometer (corrected for temperature) and dividing by 1000, the required increment can be found with a maximum error of 0·0015 inch.

Table II. has been deduced in this manner from the values of 1000 × M given in the International Tables, interpolation being resorted to where necessary. It gives the amount which must be added to readings of 27 and 30 inches respectively for every 10 feet of altitude up to 1,000 feet and for intervals of temperature of 10° F. between 0° and 90° F. The values for intermediate altitudes, temperatures and pressures must be found by interpolation. Special reduction cards are supplied by the Meteorological Office to its observers in which the amount of interpolation required is reduced to a minimum. These cards are only applicable for the altitudes for which they are made out.

In applying the correction for altitude, the temperature of the dry bulb in the screen and not that of the attached thermometer must always be used.

For the reduction of readings taken at altitudes above 1,000 feet the tables issued by the International Committee should be consulted.

Table III. Correction of barometric readings at sea level for the variation of gravity with latitude.* (*See* International Tables, Chapter IV., Section II., Table IV., pp. 179 and p. B. 31).

The table is based on the formula

$$H_1 = H\,(1 - 0{\cdot}00259 \cos 2\lambda.)$$

where H is the observed reading of the barometer at sea level in latitude λ.

H_1 is the corrected reading.

The correction is subtractive for latitudes below 45° in both hemispheres and additive for latitudes above 45°.

The table gives the amount of the correction at pressures of 27 and 30 inches respectively for each degree.

Tables IV. and V. Comparison of the Metric and the English barometric scales. (*See* International Tables, Chapter IV. Section I. Tables V. and VI. pp. 98–107 and pp. B. 24–25).

The tables are based on the relations

1 millimetre = 0·0393701 inch.
1 inch= 25·4000 millimetres.

Tables VI. and VII. Comparison of the Fahrenheit and Centigrade thermometric scales.

The relation between the two scales is as follows :—

$$\frac{5}{9}\,(T_F - 32) = T_C$$

where T_F is the temperature on the Fahrenheit scale and T_C is the corresponding temperature on the Centigrade scale.

* For particulars of the magnitude of the variation of gravity with altitude *see* International Tables, p. 39.

Tables VIII to XII for converting measurements of height, wind velocity, and rainfall in English units into metric and *vice versa* are based on the relation

$$1 \text{ inch} = 25{\cdot}4000 \text{ millimetres.}$$

Table XIII.—Glaisher's Hygrometric Factors.

Glaisher's hygrometric tables, which are generally used in the British Isles, are based on the determination of the dew point from readings of the dry and wet bulb thermometers by means of the formula

$$(t - d) = A\,(t - t')$$

where t is the temperature of the dry bulb
 t′ is the temperature of the wet bulb
 d is the temperature of the dew point
 A is a factor which depends on the temperature of the dry bulb.

The values of this factor A have been determined from the comparison of many thousand simultaneous observations of the dry and wet bulb thermometers and of the Daniell's Hygrometer taken at the Royal Observatory, Greenwich, from the year 1841 to 1854, and from observations taken at high temperature in India and others at low and medium temperatures at Toronto. Table VIII. is copied from the sixth edition of tables issued by the late Mr. Glaisher, it gives the numerical value of the factor A for each degree from 10° to 100° F.

Having thus ascertained the temperature of the dew point, the remaining hygrometric values (vapour pressure, relative humidity) can be found with the aid of a table of tension of saturated aqueous vapour. (See International Tables, Chapter V., Table II., pp. 248-252).

Special Tables, abstracted from the detailed tables computed by Mr. Glaisher, have been prepared by the Meteorological Office for the use of its observers, for computing relative humidity, vapour pressure and dew point from readings of dry and wet bulb thermometers.

The Hygrometric Tables used in other countries are based on Regnault's formula $e'' = e' - A\,(t - t')\,b$, where e′ and e″ or the vapour pressures at the temperatures of the wet bulb and the dew point respectively, t and t′ the readings of the dry and wet bulb, b the height of the barometer, and A a constant. In the last edition (1903) of Jelinek's Table, as revised by the late Professor Pernter, the values of the constant A depend on the ventilation to which the thermometers are exposed. Three cases are distinguished (1) indoor readings without the use of a fan, or outdoor screen readings on occasions of calm; (2) screen readings on occasion of light winds; (3) screen readings on occasions of moderate or strong wind, or readings obtained with Assmann's ventilated psychrometer (see p. 34) or with sling psychrometers. When the temperature of the wet bulb is below the freezing point, different values of A are introduced according as the wet bulb is coated with ice or with super-cooled water. We have thus the following six values of A (e′, e″ and b being measured in millimeters, t and t′ in centrigrade degrees): (1) wet bulb coated with water, calm 0·001200, light wind 0·000800, strong wind 0·000656; (2) wet bulb coated with ice, calm 0·001060, light wind 0·000706, strong wind 0·000579.

Jelinek's Tables are used at official stations in Austria. The tables used in other countries are in substantial agreement with Jelinek's Tables, for the cases "light wind" or "moderate wind," wet bulb coated with water, according as artificial ventilation is or is not used. Values deduced from Glaisher's Tables differ little from those computed from Jelinek's Tables at ordinary temperatures and humidities, but on occasions of great dryness and at low temperatures the differences are considerable.

TABLE I.—TEMPERATURE CORRECTION OF THE BAROMETER.—Corrections to be applied to Readings of Mercury Barometers with brass scales extending from the Cistern to the top of the Mercurial Column, to reduce them to 32° F.

Temp.	INCHES.											Temp.
	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
0°	+ ·068	+ ·069	+ ·070	+ ·072	+ ·073	+ ·074	+ ·076	+ ·077	+ ·078	+ ·080	+ ·081	0°
1	·065	·067	·068	·069	·070	·072	·073	·074	·076	·077	·078	1
2	·063	·064	·065	·067	·068	·069	·070	·072	·073	·074	·075	2
3	·061	·062	·063	·064	·065	·066	068	·069	·070	·071	·072	3
4	·058	·060	·061	·062	·063	·064	·065	·066	·067	·069	·070	4
5	·056	·057	·058	·059	·060	·061	·062	·064	·065	·066	·067	5
6	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·064	6
7	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	7
8	·049	·050	·051	·052	·053	·053	·054	·055	·056	·057	·058	8
9	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	·055	9
10	·044	·045	·046	·046	·047	·048	·049	·050	·051	·052	·053	10
11	·042	·043	·043	·044	·045	·046	·047	·047	·048	·049	·050	11
12	·039	·040	·041	·042	·042	·043	·044	·044	·045	·046	·047	12
13	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	·044	13
14	·035	·035	·036	·036	·037	·038	·039	·039	·040	·041	·041	14
15	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	·038	15
16	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	·036	16
17	·027	·028	·029	·029	·030	·030	·031	·031	·032	·032	·033	17
18	·025	·026	·026	·027	·027	·028	·028	·029	·029	·030	·030	18
19	·023	·023	·024	·024	·025	·025	·025	·026	·026	·027	·027	19
20	·020	·021	·021	·022	·022	·022	·023	·023	·024	·024	·024	20
21	·018	·018	·019	·019	·019	·020	·020	·021	·021	·021	·022	21
22	·016	·016	·016	·017	·017	·017	·017	·018	·018	·018	·019	22
23	·013	·014	·014	·014	·014	·015	·015	·015	·015	·016	·016	23
24	·011	·011	·011	·012	·012	·012	·012	·012	·013	·013	·013	24
25	·009	·009	·009	·009	·009	·009	·010	·010	·010	·010	·010	25
26	·006	·006	·006	·007	·007	·007	·007	·007	·007	·007	·007	26
27	·004	·004	·004	·004	·004	·004	·004	·004	·004	·005	·005	27
28	·001	·002	·002	·002	·002	·002	·002	·002	·002	·002	·002	28
29	− ·001	− ·001	− ·001	− ·001	− ·001	− ·001	− ·001	− ·001	− ·001	− ·001	− ·001	29
30	·003	·003	·003	·003	·003	·004	·004	·004	·004	·004	·004	30
31	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	31
32	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	·009	32
33	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	33
34	·013	·013	·013	·013	·014	·014	·014	·014	·015	·015	·015	34
35	·015	·015	·016	·016	·016	·017	·017	·017	·017	·018	·018	35
36	·017	·018	·018	·018	·019	·019	·019	·020	·020	·020	·021	36
37	·020	·020	·021	·021	·021	·022	·022	·022	·023	·023	·024	37
38	·022	·023	·023	·023	·024	·024	·025	·025	·026	·026	·026	38
39	·024	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	39
40	·027	·027	·028	·028	·029	·030	·030	·031	·031	·032	·032	40
41	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	41
42	·032	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	42
43	·034	·035	·035	·036	·036	·037	·038	·038	·039	·040	·040	43
44	·036	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	44
45	·039	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	45
46	·041	·042	·043	·043	·044	·045	·046	·047	·047	·048	·049	46
47	·043	·044	·045	·046	·047	·048	·048	·049	·050	·051	·052	47
48	·046	·047	·047	·048	·049	·050	·051	·052	·053	·054	·054	48
49	·048	·049	·050	·051	·052	·053	·054	·055	·055	·056	·057	49
50	·050	051	·052	·053	·054	·055	·056	·057	·058	·059	·060	50

NOTE.—The temperature of the "attached thermometer" should be used when applying these corrections.

TABLE 1.—TEMPERATURE CORRECTION OF THE BAROMETER.—*continued.*

Temp.	INCHES. 26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	Temp.
	–	–	–	–	–	–	–	–	–	–	–	
51°	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	51°
52	·055	·056	·057	·058	·059	·060	·061	·062	·064	·065	·066	52
53	·057	·059	·060	·061	·062	·063	·064	·065	·066	·067	·068	53
54	·060	·061	·062	·063	·064	·065	·067	068	·069	·070	·071	54
55	·062	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	55
56	·064	·066	·067	·068	·069	·070	·072	·073	·074	·076	·077	56
57	·067	·068	·069	·071	·072	·073	·075	·076	·077	·078	·080	57
58	·069	·071	·072	·073	·074	·076	·077	·078	·080	·081	·082	58
59	·072	·073	·074	·076	·077	·078	·080	·081	·083	·084	·085	59
60	·074	·075	·077	·078	·080	·081	·082	·084	·085	·087	·088	60
61	·076	·078	·079	·080	·082	·084	·085	·087	·088	·090	·091	61
62	·079	·080	·082	·083	·085	·086	·088	·089	·091	·092	·094	62
63	·081	·083	·084	·086	·087	·089	·090	·092	·093	·095	·096	63
64	·083	·085	·083	·088	·090	·092	·093	·095	·096	·097	·099	64
65	·086	·088	·089	·091	·092	·094	·095	·097	·099	·101	·102	65
66	·088	·090	·091	·093	·095	·097	·098	·100	·101	·103	·105	66
67	·090	·092	094	·096	·097	·099	·101	·102	·104	·106	·108	67
68	·093	·095	·096	·098	·100	·102	·103	·105	·107	·109	·110	68
69	·095	·097	·099	·101	·102	·104	·106	·108	·110	·112	·113	69
70	·097	·099	·101	103	·105	·107	·109	·111	·112	·114	·116	70
71	·100	·102	·103	·105	·107	·109	·111	·113	·115	·117	·119	71
72	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	72
73	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	·124	73
74	·107	·109	·111	·113	·115	·117	·119	·121	·123	·125	·127	74
75	·109	·111	·113	·115	·117	·120	·122	·124	·126	·128	·130	75
76	·111	·113	·116	·118	·120	·122	·124	·126	·128	·131	·133	76
77	·114	·116	·118	·120	·122	·125	·127	·129	·131	·134	·136	77
78	·116	·118	·120	·123	·125	·127	·129	·132	·134	·136	·138	78
79	·118	·121	·123	·125	·127	·130	·132	·135	·137	·139	·141	79
80	·121	·123	·125	·128	·130	·133	·135	·137	·139	·142	·144	80
81	·123	·126	·128	·130	·132	·135	·137	·140	·142	·145	·147	81
82	·125	·128	·130	·133	·135	·138	·140	·143	·145	·148	·149	82
83	·128	·131	·133	·136	·138	·140	·142	·145	·147	·150	·152	83
84	·130	·133	·135	·138	·140	·143	·145	·148	·150	·153	·155	84
85	·132	·135	·137	·140	·143	·146	·148	·151	·153	·156	·158	85
86	·135	·138	·140	·143	·145	·148	·150	·153	·155	·158	·161	86
87	·137	·140	·142	·145	·148	·151	·153	·156	·158	·161	·163	87
88	·139	·143	·145	·148	·150	·153	·155	·158	·161	·164	·166	88
89	·142	·145	·147	·150	·153	·156	·158	·161	·164	·167	·169	89
90	·144	·147	·150	·153	·155	·158	·161	·164	·166	·169	·172	90
91	·146	·149	·152	·155	·158	·161	·163	·166	·169	·172	·175	91
92	·149	·152	·154	·157	·160	·163	·166	·169	·172	·175	·177	92
93	·151	·154	·157	·160	·163	·166	·168	·171	·174	·177	·180	93
94	·153	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	94
95	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	·186	95
96	·158	·161	·164	·167	·170	·173	·176	·179	·182	·185	·188	96
97	·160	·164	·167	·170	·173	·176	·179	·182	·185	·188	·191	97
98	·163	·166	·169	·172	·175	178	·181	·185	·188	·191	·194	98
99	·165	·168	·171	·175	·178	·181	·184	·187	·190	·194	·197	99
100	·167	·171	·174	·177	·180	·184	·187	·190	·193	·197	·200	100

TABLE II.

Reduction of Barometer Readings to Mean Sea Level.

Reading at Station Level, **27 inches.**

Height in Feet.	TEMPERATURE OF AIR. (Dry bulb in screen.) 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	Height in Feet.
10	·011	·011	·011	·010	·010	·010	·010	·009	·009	·009	10
20	·023	·022	·021	·021	·021	·020	·020	·019	·019	·018	20
30	·034	·033	·032	·032	·031	·030	·029	·029	·028	·028	30
40	·044	·043	·042	·041	·040	·040	·039	·038	·038	·037	40
50	·056	·054	·053	·052	·050	·049	·049	·048	·047	·046	50
60	·067	·065	·064	·062	·061	·059	·058	·058	·056	·055	60
70	·078	·076	·075	·073	·071	·069	·068	·067	·066	·064	70
80	·088	·086	·085	·083	·082	·080	·078	076	·075	·073	80
90	·100	·097	·096	·094	·092	·091	·088	·085	·085	·083	90
100	·111	·108	·106	·104	·102	·100	·097	·096	·094	·091	100
110	·122	·119	·116	·115	·112	·110	·107	·105	·103	·101	110
120	·133	·130	·127	·124	·123	·120	·117	·116	·113	·110	120
130	·143	·110	·138	·135	·132	·129	·126	·123	·121	·120	130
140	·154	·151	·148	·145	·143	·139	·136	·133	·132	·129	140
150	·165	·162	·159	·156	·152	·148	·146	·143	·141	·138	150
160	·176	·173	·170	·166	·162	·159	·156	·153	·150	·147	160
170	·188	·184	·180	·177	·172	·169	·166	·162	·160	·156	170
180	·199	·194	·191	·186	·182	·178	·175	·172	·168	·166	180
190	·210	·205	·201	·196	·193	·188	·184	·182	·178	·175	190
200	·221	·216	·211	·207	·202	·199	·195	·191	·188	·184	200
210	·232	·227	·221	·217	·212	·209	·204	·201	·197	·193	210
220	·243	·238	·232	·228	·223	·219	·214	·211	·207	·203	220
230	·254	·248	·243	·238	·233	·229	·224	·220	·217	·212	230
240	·265	·259	·254	·249	·244	·238	·234	·229	·226	·222	240
250	·275	·270	·265	·259	·254	·248	·244	·239	·236	·232	250
260	·287	·281	·275	·269	·264	·258	·254	·250	·245	·241	260
270	·298	·292	·286	·280	·274	·269	·264	·260	·255	·250	270
280	·310	·302	·297	·290	·284	·279	·274	·269	·264	·260	280
290	·320	·313	·308	·301	·295	·290	·284	·279	·274	·269	290
300	·332	·324	·319	·310	·305	·300	·294	·289	·283	·278	300
310	·344	·336	·329	·321	·315	·310	·304	·299	·292	·287	310
320	·355	·346	·340	·332	·326	·320	·314	·309	·301	·296	320
330	·366	·358	·351	·343	·336	·329	·323	·318	·311	·306	330
340	·377	·369	·362	·354	·346	·338	·333	·328	·320	·315	340
350	·389	·381	·373	·364	·356	·348	·343	·337	·329	·324	350
360	·400	·391	·383	·374	·366	·358	·353	·346	·339	·333	360
370	·410	·402	·393	·385	·377	·369	·363	·355	·349	·342	370
380	·421	·413	·403	·395	·387	·379	·372	·365	·358	·352	380
390	·432	·424	·414	·406	·398	·390	·382	·374	·368	·361	390
400	·443	·435	·424	·416	·408	·400	·391	·383	·378	·370	400
410	·454	·445	·435	·427	·418	·409	·401	·393	·387	·379	410
420	·465	·456	·445	·437	·428	·420	·411	·403	·396	·388	420
430	·477	·467	·456	·448	·438	·430	·420	·412	·406	·398	430
440	·488	·478	·467	·459	·449	·441	·430	·422	·415	·407	440
450	·499	·489	·478	·470	·459	·451	·440	·432	·424	·416	450
460	·511	·499	·489	·480	·469	·461	·450	·442	·434	·426	460
470	·522	·510	·499	·490	·480	·471	·461	·452	·444	·436	470
480	·534	·521	·510	·500	·490	·480	·471	·461	·453	·445	480
490	·544	·532	·521	·511	·500	·490	·481	·471	·463	·454	490
500	·556	·543	·532	·521	·510	·499	·491	·481	·473	·464	500

TABLE II.—*continued.*

Reduction of Barometer Readings to Mean Sea Level.

Reading at Station Level, **30 inches.**

Height in Feet.	TEMPERATURE OF AIR. (Dry bulb in screen.) 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	Height in Feet.
10	·012	·012	·012	·011	·011	·011	·011	·010	·010	·010	10
20	·025	·024	·023	·023	·023	·022	·022	·021	·021	·020	20
30	·037	·036	·035	·035	·034	·033	·032	·032	·031	·031	30
40	·049	·048	·047	·046	·045	·044	·043	·042	·042	·041	40
50	·062	·060	·059	·058	·056	·055	·054	·053	·052	·051	50
60	·074	·072	·071	·069	·068	·066	·065	·064	·062	·061	60
70	·086	·084	·083	·081	·079	·077	·076	·074	·073	·071	70
80	·098	·096	·094	·092	·091	·089	·087	·085	·083	·081	80
90	·111	·108	·106	·104	·102	·101	·098	·095	·094	·092	90
100	·123	·120	·118	·115	·113	·111	·108	·106	·104	·101	100
110	·135	·132	·129	·127	·124	·122	·119	·116	·114	·112	110
120	·147	·144	·141	·138	·136	·133	·130	·127	·125	·122	120
130	·159	·156	·153	·150	·147	·143	·140	·137	·135	·133	130
140	·171	·168	·164	·161	·158	·154	·151	·148	·146	·143	140
150	·183	·180	·176	·173	·169	·165	·162	·159	·156	·153	150
160	·196	·192	·188	·184	·180	·176	·173	·170	·166	·163	160
170	·209	·204	·200	·196	·191	·187	·184	·180	·177	·173	170
180	·221	·216	·212	·207	·202	·198	·195	·191	·187	·184	180
190	·233	·228	·223	·218	·214	·209	·205	·202	·198	·194	190
200	·246	·240	·235	·230	·225	·221	·217	·212	·209	·205	200
210	·258	·252	·246	·241	·236	·232	·227	·223	·219	·215	210
220	·270	·264	·258	·253	·248	·243	·238	·234	·230	·226	220
230	·282	·276	·270	·265	·259	·254	·249	·245	·241	·236	230
240	·294	·288	·282	·277	·271	·265	·260	·255	·251	·247	240
250	·306	·300	·294	·288	·282	·276	·271	·266	·262	·258	250
260	·319	·312	·306	·299	·293	·287	·282	·278	·272	·268	260
270	·331	·324	·318	·311	·305	·299	·293	·289	·283	·278	270
280	·344	·336	·330	·322	·316	·310	·305	·299	·293	·289	280
290	·356	·348	·342	·334	·328	·322	·316	·310	·304	·299	290
300	·369	·360	·354	·345	·339	·333	·327	·321	·315	·309	300
310	·382	·373	·366	·357	·350	·344	·338	·332	·325	·319	310
320	·394	·385	·378	·369	·362	·355	·349	·343	·335	·329	320
330	·407	·398	·390	·381	·373	·365	·359	·353	·346	·340	330
340	·419	·410	·402	·393	·385	·376	·370	·364	·356	·350	340
350	·432	·423	·414	·405	·396	·387	·381	·375	·366	·360	350
360	·444	·435	·425	·416	·407	·398	·392	·385	·377	·370	360
370	·456	·447	·437	·428	·419	·410	·403	·395	·388	·380	370
380	·468	·459	·448	·439	·430	·421	·413	·406	·398	·391	380
390	·480	·471	·460	·451	·442	·433	·424	·416	·409	·401	390
400	·492	·483	·471	·462	·453	·444	·435	·426	·420	·411	400
410	·505	·495	·483	·474	·464	·455	·446	·437	·430	·421	410
420	·517	·507	·495	·486	·476	·467	·457	·448	·440	·431	420
430	·530	·519	·507	·498	·487	·478	·467	·458	·451	·442	430
440	·542	·531	·519	·510	·499	·490	·478	·469	·461	·452	440
450	·555	·543	·531	·522	·510	·501	·489	·480	·471	·462	450
460	·568	·555	·543	·533	·521	·512	·500	·491	·482	·473	460
470	·580	·567	·555	·545	·533	·523	·512	·502	·493	·484	470
480	·593	·579	·567	·556	·544	·533	·523	·512	·503	·494	480
490	·605	·591	·579	·568	·556	·544	·535	·523	·514	·505	490
500	·618	·603	·591	·579	·567	·555	·546	·534	·525	·516	500

TABLE II.—*continued.*

Reduction of Barometer Readings to Mean Sea Level.

Reading at Station Level, **27 inches.**

Height in Feet.	TEMPERATURE OF AIR. (Dry bulb in screen.)										Height in Feet.
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	
500	·556	·543	·532	·521	·510	·499	·491	·481	·473	·464	500
510	·568	·554	·543	·532	·520	·509	·501	·490	·482	·473	510
520	·579	·565	·553	·543	·531	·520	·511	·500	·492	·482	520
530	·591	·577	·564	·554	·541	·530	·520	·509	·501	·492	530
540	·601	·588	·575	·564	·552	·541	·530	·519	·511	·501	540
550	·613	·599	·586	·575	·562	·551	·540	·529	·521	·510	550
560	·624	·610	·597	·585	·572	·561	·550	·539	·530	·519	560
570	·634	·621	·607	·596	·582	·571	·561	·549	·539	·528	570
580	·645	·632	·618	·606	·592	·581	·571	·558	·549	·538	580
590	·656	·643	·629	·617	·603	·592	·581	·568	·558	·547	590
600	·667	·653	·640	·626	·613	·602	·591	·578	·567	·556	600
610	·677	·665	·651	·637	·624	·612	·601	·588	·577	·566	610
620	·689	·676	·662	·648	·634	·623	·611	·598	·587	·576	620
630	·701	·688	·672	·659	·645	·633	·620	·607	·596	·585	630
640	·712	·698	·683	·670	·656	·643	·630	·616	·606	·595	640
650	·724	·710	·694	·680	·667	·653	·640	·626	·616	·605	650
660	·735	·721	·705	·690	·677	·663	·650	·636	·625	·614	660
670	·746	·732	·715	·701	·688	·673	·660	·647	·635	·623	670
680	·758	·742	·726	·711	·697	·682	·669	·657	·644	·633	680
690	·769	·753	·737	·722	·708	·692	·679	·668	·654	·642	690
700	·780	·764	·748	·732	·718	·702	·688	·678	·664	·651	700
710	·792	·776	·759	·742	·728	·712	·698	·688	·674	·661	710
720	·803	·787	·769	·753	·739	·723	·709	·697	·684	·670	720
730	·815	·798	·780	·764	·749	·733	·719	·706	·693	·679	730
740	·825	·809	·791	·775	·760	·743	·730	·716	·703	·689	740
750	·837	·821	·802	786	·769	·753	·740	·726	·713	·699	750
760	·849	·832	·813	·796	·779	·763	·750	·736	·722	·708	760
770	·859	·842	·823	·807	·790	·774	·760	·746	·731	·717	770
780	·871	·853	·834	·818	·800	·784	·769	·755	·741	·727	780
790	·882	864	·845	·829	·811	·795	·778	·765	·750	·736	790
800	·894	·875	·856	·840	·821	·805	·788	·775	·759	·745	800
810	·905	·886	·867	·850	·832	·814	·798	·785	·769	·755	810
820	·916	·897	·877	·860	·842	·825	·809	·795	·778	·765	820
830	·928	·909	·888	·870	·853	·835	·819	·804	·787	·774	830
840	·939	·920	·899	·881	·864	·846	·830	·814	·797	·784	840
850	·950	·931	·910	·891	·875	·856	·840	·823	·807	·794	850
860	·962	·942	·922	·902	·885	·866	·850	·833	·817	·803	860
870	·974	·953	·932	·913	·895	·877	·860	·843	·827	·812	870
880	·986	·964	·944	·923	·905	·886	·870	·852	·836	·822	880
890	·998	·975	·955	·934	·916	·897	·881	·862	·846	·831	890
900	1·010	·985	·967	·945	·926	·907	·891	·872	·856	·840	900
910	1·021	·997	·977	·956	·936	·917	·901	·882	·866	·850	910
920	1·032	1·008	·988	·967	·947	·928	·911	·893	·876	·859	920
930	1·044	1·020	·999	·977	·957	·938	·920	·903	·885	·868	930
940	1·055	1·030	1·010	·988	·967	·949	·930	·913	·895	·878	940
950	1·066	1·042	1·021	·999	·977	·958	·940	·924	·904	·888	950
960	1·078	1·054	1·031	1·010	·988	·968	·950	·933	·914	·897	960
970	1·089	1·065	1·042	1·021	·999	·979	·960	·943	·925	·906	970
980	1·101	1·076	1·053	1·031	1·010	·989	·970	·952	·934	·916	980
990	1·111	1·087	1·064	1·042	1·021	1·000	·981	·962	·943	·925	990
1000	1·123	1·099	1·075	1·053	1·031	1·010	·991	·972	·953	·934	1000

TABLE II.—*continued.*

Reduction of Barometer Readings to Mean Sea Level.

Reading at Station Level, **30 inches.**

Height in Feet.	TEMPERATURE OF AIR. (Dry bulb in screen.) 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	Height in Feet.
500	·618	·603	·591	·579	·567	·555	·546	·534	·525	·516	500
510	·631	·616	·603	·591	·578	·566	·557	·545	·536	·526	510
520	·643	·628	·615	·603	·590	·578	·568	·556	·547	·536	520
530	·656	·641	·627	·615	·601	·589	·578	·566	·557	·547	530
540	·668	·653	·639	·627	·613	·601	·589	·577	·568	·557	540
550	·681	·666	·651	·639	·624	·612	·600	·588	·579	·567	550
560	·693	·678	·663	·650	·635	·623	·611	·599	·589	·577	560
570	·705	·690	·675	·662	·647	·635	·623	·610	·599	·587	570
580	·717	·702	·687	·673	·658	·646	·634	·620	·610	·598	580
590	·729	·714	·699	·685	·670	·658	·646	·631	·620	·608	590
600	·741	·726	·711	·696	·681	·669	·657	·642	·630	·618	600
610	·754	·739	·723	·708	·693	·680	·668	·653	·641	·629	610
620	·766	·751	·735	·720	·705	·692	·679	·664	·652	·640	620
630	·779	·764	·747	·732	·717	·703	·689	·674	·662	·650	630
640	·791	·776	·759	·744	·729	·715	·700	·685	·673	·661	640
650	·804	·789	·771	·756	·741	·726	·711	·696	·684	·672	650
660	·817	·801	·783	·767	·752	·737	·722	·707	·695	·682	660
670	·829	·813	·795	·779	·764	·748	·733	·719	·706	·692	670
680	·842	·825	·807	·790	·775	·758	·743	·730	·716	·703	680
690	·854	·837	·819	·802	·787	·769	·754	·742	·727	·713	690
700	·867	·849	·831	·813	·798	·780	·765	·753	·738	·723	700
710	·880	·862	·843	·825	·809	·791	·776	·764	·749	·734	710
720	·892	·874	·855	·837	·821	·803	·788	·775	·760	·745	720
730	·905	·887	·867	·849	·832	·814	·799	·785	·770	·755	730
740	·917	·899	·879	·861	·844	·826	·811	·796	·781	·766	740
750	·930	·912	·891	·873	·855	·837	·822	·807	·792	·777	750
760	·943	·924	·903	·885	·866	·848	·833	·818	·802	·787	760
770	·955	·936	·915	·897	·878	·860	·844	·829	·812	·797	770
780	·968	·948	·927	·909	·889	·871	·854	·839	·823	·808	780
790	·980	·960	·939	·921	·901	·883	·865	·850	·833	·818	790
800	·993	·972	·951	·933	·912	·894	·876	·861	·843	·828	800
810	1·006	·985	·963	·944	·924	·905	·887	·872	·854	·839	810
820	1·018	·997	·975	·956	·936	·917	·899	·883	·865	·850	820
830	1·031	1·010	·987	·967	·948	·928	·910	·893	·875	·860	830
840	1·043	1·022	·999	·979	·960	·940	·922	·904	·886	·871	840
850	1·056	1·035	1·011	·990	·972	·951	·933	·915	·897	·882	850
860	1·069	1·047	1·024	1·002	·983	·962	·944	·926	·908	·892	860
870	1·082	1·059	1·036	1·014	·995	·974	·956	·937	·919	·902	870
880	1·096	1·071	1·049	1·026	1·006	·985	·967	·947	·929	·913	880
890	1·109	1·083	1·061	1·038	1·018	·997	·979	·958	·940	·923	890
900	1·122	1·095	1·074	1·050	1·029	1·008	·990	·969	·951	·933	900
910	1·135	1·108	1·086	1·062	1·040	1·019	1·001	·980	·962	·944	910
920	1·147	1·120	1·098	1·074	1·052	1·031	1·012	·992	·973	·955	920
930	1·160	1·133	1·110	1·086	1·063	1·042	1·022	1·003	·983	·965	930
940	1·172	1·145	1·122	1·098	1·075	1·054	1·033	1·015	·994	·976	940
950	1·185	1·158	1·134	1·110	1·086	1·065	1·044	1·026	1·005	·987	950
960	1·198	1·171	1·146	1·122	1·098	1·076	1·055	1·037	1·016	·997	960
970	1·210	1·183	1·158	1·134	1·110	1·088	1·067	1·048	1·027	1·007	970
980	1·223	1·196	1·170	1·146	1·122	1·099	1·078	1·058	1·037	1·018	980
990	1·235	1·208	1·182	1·158	1·134	1·111	1·090	1·069	1·048	1·028	990
1000	1·248	1·221	1·194	1·170	1·146	1·122	1·101	1·080	1·059	1·038	1000

TABLE III.

Corrections for reducing Barometric Readings to Standard Gravity in Latitude 45°.

Lat. N. or S.	Correction. At 27 in.	Correction. At 30 in.	Lat. N. or S.	Correction. At 27 in.	Correction. At 30 in.	Lat. N. or S.	Correction. At 27 in.	Correction. At 30 in.	Lat. N. or S.	Correction. At 27 in.	Correction. At 30 in.
°											
0	-·070	-·078	23	-·049	-·054	46	+·002	+·003	69	+·052	+·058
1	·070	·078	24	·047	·052	47	·005	·005	70	·054	·060
2	·070	·078	25	·045	·050	48	·007	·008	71	·055	·061
3	·070	·077	26	·043	·048	49	·010	·011	72	·057	·063
4	·069	·077	27	·041	·046	50	·012	·013	73	·058	·064
5	·069	·077	28	·039	·043	51	·015	·016	74	059	·066
6	·068	·076	29	·037	·041	52	·017	·019	75	·061	·067
7	·068	·075	30	·035	·039	53	·019	·021	76	·062	·069
8	·067	·075	31	·033	·036	54	·022	·024	77	·063	·070
9	·067	·074	32	·031	·034	55	·024	·027	78	·064	·071
10	·066	·073	33	·028	·032	56	·026	·029	79	·065	·072
11	·065	·072	34	·026	·029	57	·028	·032	80	·066	·073
12	·064	·071	35	·024	·027	58	·031	·034	81	·067	·074
13	·063	·070	36	·022	·024	59	·033	·036	82	·067	·075
14	·062	·069	37	·019	·021	60	·035	·039	83	·068	·075
15	·061	·067	38	·017	·019	61	·037	·041	84	068	·076
16	·059	·066	39	·015	·016	62	·039	·043	85	·069	·077
17	·058	·064	40	·012	·013	63	·041	·046	86	·069	·077
18	·057	·063	41	·010	·011	64	·043	·048	87	·070	·077
19	·055	·061	42	·007	·008	65	·045	·050	88	·070	·078
20	·054	·060	43	·005	·005	66	·047	·052	89	·070	·078
21	·052	·058	44	-·002	-·003	67	·049	·054	90	+·070	+·078
22	-·050	-·056	45	± 0	± 0	68	+·050	+·056			

B. Conversion Tables.

TABLE IV.

Conversion of Inches to Millimetres.

(1 inch = 25·3995 millimetres.)

English Inches and Tenths.	0	1	2	3	4	5	6	7	8	9
	Hundredths of an Inch.									
27·0	685·79	686·04	686·30	686·55	686·80	687·06	687·31	687·57	687·82	688·07
·1	688·33	688·58	688·84	689·09	689·34	689·60	689·85	690·11	690·36	690·61
·2	690·87	691·12	691·38	691·63	691·88	692·14	692·39	692·65	692·90	693·15
·3	693·41	693·66	693·92	694·17	694·42	694·68	694·93	695·19	695·44	695·69
·4	695·95	696·20	696·46	696·71	696·96	697·22	697·47	697·73	697·98	698·23
·5	698·49	698·74	699·00	699·25	699·50	699·76	700·01	700·27	700·52	700·77
·6	701·03	701·28	701·54	701·79	702·04	702·30	702·55	702·81	703·06	703·31
·7	703·57	703·82	704·08	704·33	704·58	704·84	705·09	705·35	705·60	705·85
·8	706·11	706·36	706·62	706·87	707·12	707·38	707·63	707·89	708·14	708·39
·9	708·65	708·90	709·16	709·41	709·66	709·92	710·17	710·43	710·68	710·93
28·0	711·19	711·44	711·70	711·95	712·20	712·46	712·71	712·97	713·22	713·47
·1	713·73	713·98	714·24	714·49	714·74	715·00	715·25	715·51	715·76	716·01
·2	716·27	716·52	716·78	717·03	717·28	717·54	717·79	718·04	718·30	718·55
·3	718·81	719·06	719·31	719·57	719·82	720·08	720·33	720·58	720·84	721·09
·4	721·35	721·60	721·85	722·11	722·36	722·62	722·87	723·12	723·38	723·63
·5	723·89	724·14	724·39	724·65	724·90	725·16	725·41	725·66	725·92	726·17
·6	726·43	726·68	726·93	727·19	727·44	727·70	727·95	728·20	728·46	728·71
·7	728·97	729·22	729·47	729·73	729·98	730·24	730·49	730·74	731·00	731·25
·8	731·51	731·76	732·01	732·27	732·52	732·78	733·03	733·28	733·54	733·79
·9	734·05	734·30	734·55	734·81	735·06	735·32	735·57	735·82	736·08	736·33
29·0	736·59	736·84	737·09	737·35	737·60	737·86	738·11	738·36	738·62	738·87
·1	739·13	739·38	739·63	739·89	740·14	740·40	740·65	740·90	741·16	741·41
·2	741·67	741·92	742·17	742·43	742·68	742·94	743·19	743·44	743·70	743·95
·3	744·21	744·46	744·71	744·97	745·22	745·48	745·73	745·98	746·24	746·49
·4	746·75	747·00	747·25	747·51	747·76	748·02	748·27	748·52	748·78	749·03
·5	749·29	749·54	749·79	750·05	750·30	750·56	750·81	751·06	751·32	751·57
·6	751·83	752·08	752·33	752·59	752·84	753·10	753·35	753·60	753·86	754·11
·7	754·37	754·62	754·87	755·13	755·38	755·64	755·89	756·14	756·40	756·65
·8	756·91	757·16	757·41	757·67	757·92	758·18	758·43	758·68	758·94	759·19
·9	759·45	759·70	759·95	760·21	760·46	760·72	760·97	761·22	761·48	761·73
30·0	761·99	762·24	762·49	762·75	763·00	763·26	763·51	763·76	764·02	764·27
·1	764·53	764·78	765·03	765·29	765·54	765·80	766·05	766·30	766·56	766·81
·2	767·07	767·32	767·57	767·83	768·08	768·34	768·59	768·84	769·10	769·35
·3	769·61	769·86	770·11	770·37	770·62	770·88	771·13	771·38	771·64	771·89
·4	772·15	772·40	772·65	772·91	773·16	773·42	773·67	773·92	774·18	774·43
·5	774·69	774·94	775·19	775·45	775·70	775·96	776·21	776·46	776·72	776·97
·6	777·23	777·48	777·73	777·99	778·24	778·50	778·75	779·00	779·26	779·51
·7	779·77	780·02	780·27	780·53	780·78	781·04	781·29	781·54	781·80	782·05
·8	782·31	782·56	782·81	783·07	783·32	783·58	783·83	784·08	784·34	784·59
·9	784·85	785·10	785·35	785·61	785·86	786·12	786·37	786·62	786·88	787·13
31·0	787·39	787·64	787·89	788·15	788·40	788·66	788·91	789·16	789·42	789·67
·1	789·93	790·18	790·43	790·69	790·94	791·20	791·45	791·70	791·96	792·21
·2	792·47	792·72	792·97	793·23	793·48	793·74	793·99	794·24	794·50	794·75
·3	795·01	795·26	795·51	795·77	796·02	796·28	796·53	796·78	797·04	797·29
·4	797·55	797·80	798·05	798·31	798·56	798·82	799·07	799·32	799·58	799·83

Inch.	Mill
1	25·400
2	50·799
3	76·199
4	101·598
5	126·998
6	152·397
7	177·797
8	203·196
9	228·596
10	253·995

Thousandths of an Inch.	1	2	3	4	5	6	7	8	9
Mm.	0·03	0·05	0·08	0·10	0·13	0·15	0·18	0·20	0·23

Conversion Tables—*continued.*

TABLE V.

Conversion of Millimetres to Inches.

(1 Metre = 39·371 Inches.)

Millimetres.	Tenths of a Millimetre. 0	1	2	3	4	5	6	7	8	9
	English Inches.									
705	27·756	27·760	27·764	27·768	27·772	27·776	27·780	27·784	27·788	27·792
6	·796	·800	·804	·808	·812	·815	·819	·823	·827	·831
7	·835	·839	·843	·847	·851	·855	·859	·863	·867	·871
8	·875	·878	·882	·886	·890	·894	·898	·902	·906	·910
9	27·914	27·918	27·922	27·926	27·930	27·934	27·938	27·941	27·945	27·949
710	27·953	27·957	27·961	27·965	27·969	27·973	27·977	27·981	27·985	27·989
1	27·993	27·997	28·001	28·004	28·008	28·012	28·016	28·020	28·024	28·028
2	28·032	28·036	·040	·044	·048	·052	·056	·060	·063	·067
3	·071	·075	·079	·083	·087	·091	·095	·099	·103	·107
4	28·111	28·115	28·119	28·123	28·126	28·130	28·134	28·138	28·142	28·146
715	28·150	28·154	28·158	28·162	28·166	28·170	28·174	28·178	28·182	28·186
6	·189	·193	·197	·201	·205	·209	·213	·217	·221	·225
7	·229	·233	·237	·241	·245	·249	·252	·256	·260	·264
8	·268	·272	·276	·280	·284	·288	·292	·296	·300	·304
9	28·308	28·312	28·315	28·319	28·323	28·327	28·331	28·335	28·339	28·343
720	28·347	28·351	28·355	28·359	28·363	28·367	28·371	28·375	28·378	28·382
1	·386	·390	·394	·398	·402	·406	·410	·414	·418	·422
2	·426	·430	·434	·438	·441	·445	·449	·453	·457	·461
3	·465	·469	·473	·477	·481	·485	·489	·493	·497	·501
4	28·504	28·508	28·512	28·516	28·520	28·524	28·528	28·532	28·536	28·540
725	28·544	28·548	28·552	28·556	28·560	28·564	28·567	28·571	28·575	28·579
6	·583	·587	·591	·595	·599	·603	·607	·611	·615	·619
7	·623	·627	·630	·634	·638	·642	·646	·650	·654	·658
8	·662	·666	·670	·674	·678	·682	·686	·689	·693	·697
9	28·701	28·705	28·709	28·713	28·717	28·721	28·725	28·729	28·733	28·737
730	28·741	28·745	28·749	28·752	28·756	28·760	28·764	28·768	28·772	28·776
1	·780	·784	·788	·792	·796	·800	·804	·808	·812	·815
2	·819	·823	·827	·831	·835	·839	·843	·847	·851	·855
3	·859	·863	·867	·871	·875	·878	·882	·886	·890	·894
4	28·898	28·902	28·906	28·910	28·914	28·918	28·922	28·926	28·930	28·934
735	28·938	28·941	28·945	28·949	28·953	28·957	28·961	28·965	28·969	28·973
6	28·977	28·981	28·985	28·989	28·993	28·997	29·001	29·004	29·008	29·012
7	29·016	29·020	29·024	29·028	29·032	29·036	·040	·044	·048	·052
8	·056	·060	·064	·067	·071	·075	·079	·083	·087	·091
9	29·095	29·099	29·103	29·107	29·111	29·115	29·119	29·123	29·127	29·130
740	29·134	29·138	29·142	29·146	29·150	29·154	29·158	29·162	29·166	29·170
1	·174	·178	·182	·186	·190	·193	·197	·201	·205	·209
2	·213	·217	·221	·225	·229	·233	·237	·241	·245	·249
3	·252	·256	·260	·264	·268	·272	·276	·280	·284	·288
4	29·292	29·296	29·300	29·304	29·308	29·312	29·315	29·319	29·323	29·327
745	29·331	29·335	29·339	29·343	29·347	29·351	29·355	29·359	29·363	29·367
6	·371	·375	·378	·382	·386	·390	·394	·398	·402	·406
7	·410	·414	·418	·422	·426	·430	·434	·438	·441	·445
8	·449	·453	·457	·461	·465	·469	·473	·477	·481	·485
9	29·489	29·493	29·497	29·501	29·504	29·508	29·512	29·516	29·520	29·524
750	29·528	29·532	29·536	29·540	29·544	29·548	29·552	29·556	29·560	29·564
1	·567	·571	·575	·579	·583	·587	·591	·595	·599	·603
2	·607	·611	·615	·619	·623	·627	·630	·634	·638	·642
3	·646	·650	·654	·658	·662	·666	·670	·674	·678	·682
4	29·686	29·690	29·693	29·697	29·701	29·705	29·709	29·713	29·717	29·721

TABLE V.—*continued.*

CONVERSION of MILLIMETRES to INCHES.

(1 Metre = 39·371 Inches.)

Millimetres.	Tenths of a Millimetre.									
	0	1	2	3	4	5	6	7	8	9
	English Inches.									
755	29·725	29·729	29·733	29·737	29·741	29·745	29·749	29·753	29·756	29·760
6	·764	·768	·772	·776	·780	·784	·788	·792	·796	·800
7	·804	·808	·812	·815	·819	·823	·827	·831	·835	·839
8	·843	·847	·851	·855	·859	·863	·867	·871	·875	·878
9	29·882	29·886	29·890	29·894	29·898	29·902	29·906	29·910	29·914	29·918
760	29·922	29·926	29·930	29·934	29·938	29·941	29·945	29·949	29·953	29·957
1	29·961	29·965	29·969	29·973	29·977	29·981	29·985	29·989	29·993	29·997
2	30·001	30·004	30·008	30·012	30·016	30·020	30·024	30·028	30·032	30·036
3	·040	·044	·048	·052	·056	·060	·064	·067	·071	·075
4	30·079	30·083	30·087	30·091	30·095	30·099	30·103	30·107	30·111	30·115
765	30·119	30·123	30·127	30·130	30·134	30·138	30·142	30·146	30·150	30·154
6	·158	·162	·166	·170	·174	·178	·182	·186	·190	·193
7	·197	·201	·205	·209	·213	·217	·221	·225	·229	·233
8	·237	·241	·245	·249	·253	·256	·260	·264	·268	·272
9	30·276	30·280	30·284	30·288	30·292	30·296	30·300	30·304	30·308	30·312
770	30·316	30·319	30·323	30·327	30·331	30·335	30·339	30·343	30·347	30·351
1	·355	·359	·363	·367	·371	·375	·379	·382	·386	·390
2	·394	·398	·402	·406	·410	·414	·418	·422	·426	·430
3	·434	·438	·441	·445	·449	·453	·457	·461	·465	·469
4	30·473	30·477	30·481	30·485	30·489	30·493	30·497	30·501	30·504	30·508
775	30·512	30·516	30·520	30·524	30·528	30·532	30·536	30·540	30·544	30·548
6	·552	·556	·560	·564	·567	·571	·575	·579	·583	·587
7	·591	·595	·599	·603	·607	·611	·615	·619	·623	·627
8	·630	·634	·638	·642	·646	·650	·654	·658	·662	·666
9	30·670	30·674	30·678	30·682	30·686	30·690	30·693	30·697	30·701	30·705
780	30·709	30·713	30·717	30·721	30·725	30·729	30·733	30·737	30·741	30·745
1	·749	·753	·756	·760	·764	·768	·772	·776	·780	·784
2	·788	·792	·796	·800	·804	·808	·812	·816	·819	·823
3	·827	·831	·835	·839	·843	·847	·851	·855	·859	·863
4	30·867	30·871	30·875	30·879	30·882	30·886	30·890	30·894	30·898	30·902
785	30·906	30·910	30·914	30·918	30·922	30·926	30·930	30·934	30·938	30·942
6	·945	·949	·953	·957	30·961	30·965	30·969	30·973	30·977	30·981
7	30·985	30·989	30·993	30·997	31·001	31·004	31·008	31·012	31·016	31·020
8	31·024	31·028	31·032	31·036	·040	·044	·048	·052	·056	·060
9	31·064	31·067	31·071	31·075	31·079	31·083	31·087	31·091	31·095	31·099
790	31·103	31·106	31·110	31·114	31·118	31·122	31·126	31·130	31·134	31·138
1	·143	·146	·150	·154	·158	·162	·166	·170	·174	·178
2	·182	·185	·189	·193	·197	·201	·205	·209	·213	·217
3	·222	·225	·229	·233	·237	·241	·245	·249	·253	·257
4	31·261	31·264	31·268	31·272	31·276	31·280	31·284	31·288	31·292	31·296
795	31·300	31·303	31·307	31·311	31·315	31·319	31·323	31·327	31·331	31·335
6	·340	·343	·346	·350	·354	·358	·362	·366	·370	·374
7	·379	·382	·386	·390	·394	·398	·402	·406	·410	·414
8	·419	·422	·425	·429	·433	·437	·441	·445	·449	·453
9	31·458	31·461	31·464	31·468	31·472	31·476	31·480	31·484	31·488	31·492

Parts.

Mill.	Inch.
1	0·0394
2	·0787
3	·1181
4	·1575
5	·1969
6	·2362
7	·2756
8	·3150
9	·3543
10	·3937

TABLE VI.

Conversion of Centigrade Degrees into Degrees of Fahrenheit

Centi-grade Degrees.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
°										
−39	−38·2	−38·4	−38·6	−38·7	−38·9	−39·1	−39·3	−39·5	−39·6	−39·8
38	36·4	36·6	36·8	36·9	37·1	37·3	37·5	37·7	37·8	38·0
37	34·6	34·8	35·0	35·1	35·3	35·5	35·7	35·9	36·0	36·2
36	32·8	33·0	33·2	33·3	33·5	33·7	33·9	34·1	34·2	34·4
35	31·0	31·2	31·4	31·5	31·7	31·9	32·1	32·3	32·4	32·6
34	29·2	29·4	29·6	29·7	29·9	30·1	30·3	30·5	30·6	30·8
33	27·4	27·6	27·8	27·9	28·1	28·3	28·5	28·7	28·8	29·0
32	25·6	25·8	26·0	26·1	26·3	26·5	26·7	26·9	27·0	27·2
31	23·8	24·0	24·2	24·3	24·5	24·7	24·9	25·1	25·2	25·4
30	22·0	22·2	22·4	22·5	22·7	22·9	23·1	23·3	23·4	23·6
29	20·2	20·4	20·6	20·7	20·9	21·1	21·3	21·5	21·6	21·8
28	18·4	18·6	18·8	18·9	19·1	19·3	19·5	19·7	19·8	20·0
27	16·6	16·8	17·0	17·1	17·3	17·5	17·7	17·9	18·0	18·2
26	14·8	15·0	15·2	15·3	15·5	15·7	15·9	16·1	16·2	16·4
25	13·0	13·2	13·4	13·5	13·7	13·9	14·1	14·3	14·4	14·6
24	11·2	11·4	11·6	11·7	11·9	12·1	12·3	12·5	12·6	12·8
23	9·4	9·6	9·8	9·9	10·1	10·3	10·5	10·7	10·8	11·0
22	7·6	7·8	8·0	8·1	8·3	8·5	8·7	8·9	9·0	9·2
21	5·8	6·0	6·2	6·3	6·5	6·7	6·9	7·1	7·2	7·4
20	4·0	4·2	4·4	4·5	4·7	4·9	5·1	5·3	5·4	5·6
19	2·2	2·4	2·6	2·7	2·9	3·1	3·3	3·5	3·6	3·8
18	−0·4	−0·6	−0·8	−0·9	−1·1	−1·3	−1·5	−1·7	−1·8	− 2·0
17	+1·4	+1·2	+1·0	+0·9	+0·7	+0·5	+0·3	+0·1	0·0	− 0·2
16	3·2	3·0	2·8	2·7	2·5	2·3	2·1	1·9	+1·8	+ 1·6
15	5·0	4·8	4·6	4·5	4·3	4·1	3·9	3·7	3·6	3·4
14	6·8	6·6	6·4	6·3	6·1	5·9	5·7	5·5	5·4	5·2
13	8·6	8·4	8·2	8·1	7·9	7·7	7·5	7·3	7·2	7·0
12	10·4	10·2	10·0	9·9	9·7	9·5	9·3	9·1	9·0	8·8
11	12·2	12·0	11·8	11·7	11·5	11·3	11·1	10·9	10·8	10·6
10	14·0	13·8	13·6	13·5	13·3	13·1	12·9	12·7	12·6	12·4
9	15·8	15·6	15·4	15·3	15·1	14·9	14·7	14·5	14·4	14·2
8	17·6	17·4	17·2	17·1	16·9	16·7	16·5	16·3	16·2	16·0
7	19·4	19·2	19·0	18·9	18·7	18·5	18·3	18·1	18·0	17·8
6	21·2	21·0	20·8	20·7	20·5	20·3	20·1	19·9	19·8	19·6
5	23·0	22·8	22·6	22·5	22·3	22·1	21·9	21·7	21·6	21·4
4	24·8	24·6	24·4	24·3	24·1	23·9	23·7	23·5	23·4	23·2
3	26·6	26·4	26·2	26·1	25·9	25·7	25·5	25·3	25·2	25·0
2	28·4	28·2	28·0	27·9	27·7	27·5	27·3	27·1	27·0	26·8
−1	30·2	30·0	29·8	29·7	29·5	29·3	29·1	28·9	28·8	28·6
0	+32·0	+31·8	+31·6	+31·5	+31·3	+31·1	+30·9	+30·7	+30·6	+30·4

Between − 40° C. and − 17·8° C. temperatures on both scales are negative; between − 17·8° C. and 0° C. temperatures on the Fahrenheit scale are positive.

TABLE VI.—*continued.*

CONVERSION of CENTIGRADE DEGREES into DEGREES of FAHRENHEIT.

Centigrade Degrees.	Tenths of Degrees.									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
° + 0	+32·0	+32·2	+32·4	+32·5	+32·7	+32·9	+33·1	+33·3	+33·4	+33·6
1	33·8	34·0	34·2	34·3	34·5	34·7	34·9	35·1	35·2	35·4
2	35·6	35·8	36·0	36·1	36·3	36·5	36·7	36·9	37·0	37·2
3	37·4	37·6	37·8	37·9	38·1	38·3	38·5	38·7	38·8	39·0
4	39·2	39·4	39·6	39·7	39·9	40·1	40·3	40·5	40·6	40·8
5	41·0	41·2	41·4	41·5	41·7	41·9	42·1	42·3	42·4	42·6
6	42·8	43·0	43·2	43·3	43·5	43·7	43·9	44·1	44·2	44·4
7	44·6	44·8	45·0	45·1	45·3	45·5	45·7	45·9	46·0	46·2
8	46·4	46·6	46·8	46·9	47·1	47·3	47·5	47·7	47·8	48·0
9	48·2	48·4	48·6	48·7	48·9	49·1	49·3	49·5	49·6	49·8
10	50·0	50·2	50·4	50·5	50·7	50·9	51·1	51·3	51·4	51·6
11	51·8	52·0	52·2	52·3	52·5	52·7	52·9	53·1	53·2	53·4
12	53·6	53·8	54·0	54·1	54·3	54·5	54·7	54·9	55·0	55·2
13	55·4	55·6	55·8	55·9	56·1	56·3	56·5	56·7	56·8	57·0
14	57·2	57·4	57·6	57·7	57·9	58·1	58·3	58·5	58·6	58·8
15	59·0	59·2	59·4	59·5	59·7	59·9	60·1	60·3	60·4	60·6
16	60·8	61·0	61·2	61·3	61·5	61·7	61·9	62·1	62·2	62·4
17	62·6	62·8	63·0	63·1	63·3	63·5	63·7	63·9	64·0	64·2
18	64·4	64·6	64·8	64·9	65·1	65·3	65·5	65·7	65·8	66·0
19	66·2	66·4	66·6	66·7	66·9	67·1	67·3	67·5	67·6	67·8
20	68·0	68·2	68·4	68·5	68·7	68·9	69·1	69·3	69·4	69·6
21	69·8	70·0	70·2	70·3	70·5	70·7	70·9	71·1	71·2	71·4
22	71·6	71·8	72·0	72·1	72·3	72·5	72·7	72·9	73·0	73·2
23	73·4	73·6	73·8	73·9	74·1	74·3	74·5	74·7	74·8	75·0
24	75·2	75·4	75·6	75·7	75·9	76·1	76·3	76·5	76·6	76·8
25	77·0	77·2	77·4	77·5	77·7	77·9	78·1	78·3	78·4	78·6
26	78·8	79·0	79·2	79·3	79·5	79·7	79·9	80·1	80·2	80·4
27	80·6	80·8	81·0	81·1	81·3	81·5	81·7	81·9	82·0	82·2
28	82·4	82·6	82·8	82·9	83·1	83·3	83·5	83·7	83·8	84·0
29	84·2	84·4	84·6	84·7	84·9	85·1	85·3	85·5	85·6	85·8
30	86·0	86·2	86·4	86·5	86·7	86·9	87·1	87·3	87·4	87·6
31	87·8	88·0	88·2	88·3	88·5	88·7	88·9	89·1	89·2	89·4
32	89·6	89·8	90·0	90·1	90·3	90·5	90·7	90·9	91·0	91·2
33	91·4	91·6	91·8	91·9	92·1	92·3	92·5	92·7	92·8	93·0
34	93·2	93·4	93·6	93·7	93·9	94·1	94·3	94·5	94·6	94·8
35	95·0	95·2	95·4	95·5	95·7	95·9	96·1	96·3	96·4	96·6
36	96·8	97·0	97·2	97·3	97·5	97·7	97·9	98·1	98·2	98·4
37	98·6	98·8	99·0	99·1	99·3	99·5	99·7	99·9	100·0	100·2
38	100·4	100·6	100·8	100·9	101·1	101·3	101·5	101·7	101·8	102·0
+39	+102·2	+102·4	+102·6	+102·7	+102·9	+103·1	+103·3	+103·5	+103·6	+103·8

TABLE VI.—*continued.*

CONVERSION of CENTIGRADE DEGREES into DEGREES of FAHRENHEIT.

Centigrade Degrees.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
° + 40	+104·0	+104·2	+104·4	+104·5	+104·7	+104·9	+105·1	+105·3	+105·4	+105·6
41	105·8	106·0	106·2	106·3	106·5	106·7	106·9	107·1	107·2	107·4
42	107·6	107·8	108·0	108·1	108·3	108·5	108·7	108·9	109·0	109·2
43	109·4	109·6	109·8	109·9	110·1	110·3	110·5	110·7	110·8	111·0
44	111·2	111·4	111·6	111·7	111·9	112·1	112·3	112·5	112·6	112·8
45	113·0	113·2	113·4	113·5	113·7	113·9	114·1	114·3	114·4	114·6
46	114·8	115·0	115·2	115·3	115·5	115·7	115·9	116·1	116·2	116·4
47	116·6	116·8	117·0	117·1	117·3	117·5	117·7	117·9	118·0	118·2
48	118·4	118·6	118·8	118·9	119·1	119·3	119·5	119·7	119·8	120·0
49	120·2	120·4	120·6	120·7	120·9	121·1	121·3	121·5	121·6	121·8
50	122·0	122·2	122·4	122·5	122·7	122·9	123·1	123·3	123·4	123·6
51	123·8	124·0	124·2	124·3	124·5	124·7	124·9	125·1	125·2	125·4
52	125·6	125·8	126·0	126·1	126·3	126·5	126·7	126·9	127·0	127·2
53	127·4	127·6	127·8	127·9	128·1	128·3	128·5	128·7	128·8	129·0
54	129·2	129·4	129·6	129·7	129·9	130·1	130·3	130·5	130·6	130·8
55	131·0	131·2	131·4	131·5	131·7	131·9	132·1	132·3	132·4	132·6
56	132·8	133·0	133·2	133·3	133·5	133·7	133·9	134·1	134·2	134·4
57	134·6	134·8	135·0	135·1	135·3	135·5	135·7	135·9	136·0	136·2
58	136·4	136·6	136·8	136·9	137·1	137·3	137·5	137·7	137·8	138·0
59	138·2	138·4	138·6	138·7	138·9	139·1	139·3	139·5	139·6	139·8
60	140·0	140·2	140·4	140·5	140·7	140·9	141·1	141·3	141·4	141·6
61	141·8	142·0	142·2	142·3	142·5	142·7	142·9	143·1	143·2	143·4
62	143·6	143·8	144·0	144·1	144·3	144·5	144·7	144·9	145·0	145·2
63	145·4	145·6	145·8	145·9	146·1	146·3	146·5	146·7	146·8	147·0
64	147·2	147·4	147·6	147·7	147·9	148·1	148·3	148·5	148·6	148·8
65	149·0	149·2	149·4	149·5	149·7	149·9	150·1	150·3	150·4	150·6
66	150·8	151·0	151·2	151·3	151·5	151·7	151·9	152·1	152·2	152·4
67	152·6	152·8	153·0	153·1	153·3	153·5	153·7	153·9	154·0	154·2
68	154·4	154·6	154·8	154·9	155·1	155·3	155·5	155·7	155·8	156·0
69	156·2	156·4	156·6	156·7	156·9	157·1	157·3	157·5	157·6	157·8
70	158·0	158·2	158·4	158·5	158·7	158·9	159·1	159·3	159·4	159·6
71	159·8	160·0	160·2	160·3	160·5	160·7	160·9	161·1	161·2	161·4
72	161·6	161·8	162·0	162·1	162·3	162·5	162·7	162·9	163·0	163·2
73	163·4	163·6	163·8	163·9	164·1	164·3	164·5	164·7	164·8	165·0
74	165·2	165·4	165·6	165·7	165·9	166·1	166·3	166·5	166·6	166·8
75	167·0	167·2	167·4	167·5	167·7	167·9	168·1	168·3	168·4	168·6
76	168·8	169·0	169·2	169·3	169·5	169·7	169·9	170·1	170·2	170·4
77	170·6	170·8	171·0	171·1	171·3	171·5	171·7	171·9	172·0	172·2
78	172·4	172·6	172·8	172·9	173·1	173·3	173·5	173·7	173·8	174·0
79	174·2	174·4	174·6	174·7	174·9	175·1	175·3	175·5	175·6	175·8

TABLE VII.

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

To convert to the Absolute Scale add 273° to the Centigrade reading.

Degrees of Fah.	Tenths of Degrees.										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
° 32	0·0	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·6	° 31
33	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·1	1·1	30
34	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·6	1·6	1·7	29
35	1·7	1·7	1·8	1·8	1·9	1·9	2·0	2·1	2·1	2·2	2·2	28
36	2·2	2·3	2·3	2·4	2·4	2·5	2·6	2·6	2·7	2·7	2·8	27
37	2·8	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·2	3·3	3·3	26
38	3·3	3·4	3·4	3·5	3·6	3·6	3·7	3·7	3·8	3·8	3·9	25
39	3·9	3·9	4·0	4·1	4·1	4·2	4·2	4·3	4·3	4·4	4·4	24
40	4·4	4·5	4·6	4·6	4·7	4·7	4·8	4·8	4·9	4·9	5·0	23
41	5·0	5·1	5·1	5·2	5·2	5·3	5·3	5·4	5·4	5·5	5·6	22
42	5·6	5·6	5·7	5·7	5·8	5·8	5·9	5·9	6·0	6·1	6·1	21
43	6·1	6·2	6·2	6·3	6·3	6·4	6·4	6·5	6·6	6·6	6·7	20
44	6·7	6·7	6·8	6·8	6·9	6·9	7·0	7·1	7·1	7·2	7·2	19
45	7·2	7·3	7·3	7·4	7·4	7·5	7·6	7·6	7·7	7·7	7·8	18
46	7·8	7·8	7·9	7·9	8·0	8·1	8·1	8·2	8·2	8·3	8·3	17
47	8·3	8·4	8·4	8·5	8·6	8·6	8·7	8·7	8·8	8·8	8·9	16
48	8·9	8·9	9·0	9·1	9·1	9·2	9·2	9·3	9·3	9·4	9·4	15
49	9·4	9·5	9·6	9·6	9·7	9·7	9·8	9·8	9·9	9·9	10·0	14
50	10·0	10·1	10·1	10·2	10·2	10·3	10·3	10·4	10·4	10·5	10·6	13
51	10·6	10·6	10·7	10·7	10·8	10·8	10·9	10·9	11·0	11·1	11·1	12
52	11·1	11·2	11·2	11·3	11·3	11·4	11·4	11·5	11·6	11·6	11·7	11
53	11·7	11·7	11·8	11·8	11·9	11·9	12·0	12·1	12·1	12·2	12·2	10
54	12·2	12·3	12·3	12·4	12·4	12·5	12·6	12·6	12·7	12·7	12·8	9
55	12·8	12·8	12·9	12·9	13·0	13·1	13·1	13·2	13·2	13·3	13·3	8
56	13·3	13·4	13·4	13·5	13·6	13·6	13·7	13·7	13·8	13·8	13·9	7
57	13·9	13·9	14·0	14·1	14·1	14·2	14·2	14·3	14·3	14·4	14·4	6
58	14·4	14·5	14·6	14·6	14·7	14·7	14·8	14·8	14·9	14·9	15·0	5
59	15·0	15·1	15·1	15·2	15·2	15·3	15·3	15·4	15·4	15·5	15·6	4
60	15·6	15·6	15·7	15·7	15·8	15·8	15·9	15·9	16·0	16·1	16·1	3
61	16·1	16·2	16·2	16·3	16·3	16·4	16·4	16·5	16·6	16·6	16·7	2
62	16·7	16·7	16·8	16·8	16·9	16·9	17·0	17·1	17·1	17·2	17·2	1
63	17·2	17·3	17·3	17·4	17·4	17·5	17·6	17·6	17·7	17·7	17·8	0
		9	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	Degrees of Fah.
	Tenths of Degrees											

The Centigrade values corresponding with the degrees of Fah., as shown in the right-hand column, require the *minus* sign.

TABLE VII.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.		Tenths of Degrees.									
Plus.	Minus.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
° 64	° 0	17·8	17·8	17·9	17·9	18·0	18·1	18·1	18·2	18·2	18·3
65	1	18·3	18·4	18·4	18·5	18·6	18·6	18·7	18·7	18·8	18·8
66	2	18·9	18·9	19·0	19·1	19·1	19·2	19·2	19·3	19·3	19·4
67	3	19·4	19·5	19·6	19·6	19·7	19·7	19·8	19·8	19·9	19·9
68	4	20·0	20·1	20·1	20·2	20·2	20·3	20·3	20·4	20·4	20·5
69	5	20·6	20·6	20·7	20·7	20·8	20·8	20·9	20·9	21·0	21·1
70	6	21·1	21·2	21·2	21·3	21·3	21·4	21·4	21·5	21·6	21·6
71	7	21·7	21·7	21·8	21·8	21·9	21·9	22·0	22·1	22·1	22·2
72	8	22·2	22·3	22·3	22·4	22·4	22·5	22·6	22·6	22·7	22·7
73	9	22·8	22·8	22·9	22·9	23·0	23·1	23·1	23·2	23·2	23·3
74	10	23·3	23·4	23·4	23·5	23·6	23·6	23·7	23·7	23·8	23·8
75	11	23·9	23·9	24·0	24·1	24·1	24·2	24·2	24·3	24·3	24·4
76	12	24·4	24·5	24·6	24·6	24·7	24·7	24·8	24·8	24·9	24·9
77	13	25·0	25·1	25·1	25·2	25·2	25·3	25·3	25·4	25·4	25·5
78	14	25·6	25·6	25·7	25·7	25·8	25·8	25·9	25·9	26·0	26·1
79	15	26·1	26·2	26·2	26·3	26·3	26·4	26·4	26·5	26·6	26·6
80	16	26·7	26·7	26·8	26·8	26·9	26·9	27·0	27·1	27·1	27·2
81	17	27·2	27·3	27·3	27·4	27·4	27·5	27·6	27·6	27·7	27·7
82	18	27·8	27·8	27·9	27·9	28·0	28·1	28·1	28·2	28·2	28·3
83	19	28·3	28·4	28·4	28·5	28·6	28·6	28·7	28·7	28·8	28·8
84	20	28·9	28·9	29·0	29·1	29·1	29·2	29·2	29·3	29·3	29·4
85	21	29·4	29·5	29·6	29·6	29·7	29·7	29·8	29·8	29·9	29·9
86	22	30·0	30·1	30·1	30·2	30·2	30·3	30·3	30·4	30·4	30·5
87	23	30·6	30·6	30·7	30·7	30·8	30·8	30·9	30·9	31·0	31·1
88	24	31·1	31·2	31·2	31·3	31·3	31·4	31·4	31·5	31·6	31·6
89	25	31·7	31·7	31·8	31·8	31·9	31·9	32·0	32·1	32·1	32·2
90	26	32·2	32·3	32·3	32·4	32·4	32·5	32·6	32·6	32·7	32·7
91	27	32·8	32·8	32·9	32·9	33·0	33·1	33·1	33·2	33·2	33·3
92	28	33·3	33·4	33·4	33·5	33·6	33·6	33·7	33·7	33·8	33·8
93	29	33·9	33·9	34·0	34·1	34·1	34·2	34·2	34·3	34·3	34·4
94	30	34·4	34·5	34·6	34·6	34·7	34·7	34·8	34·8	34·9	34·9
95	31	35·0	35·1	35·1	35·2	35·2	35·3	35·3	35·4	35·4	35·5
96	32	35·6	35·6	35·7	35·7	35·8	35·8	35·9	35·9	36·0	36·1
97	33	36·1	36·2	36·2	36·3	36·3	36·4	36·4	36·5	36·6	36·6
98	34	36·7	36·7	36·8	36·8	36·9	36·9	37·0	37·1	37·1	37·2
99	35	37·2	37·3	37·3	37·4	37·4	37·5	37·6	37·6	37·7	37·7
100	36	37·8	37·8	37·9	37·9	38·0	38·1	38·1	38·2	38·2	38·3
101	37	38·3	38·4	38·4	38·5	38·6	38·6	38·7	38·7	38·8	38·8
102	38	38·9	38·9	39·0	39·1	39·1	39·2	39·2	39·3	39·3	39·4
103	39	39·4	39·5	39·6	39·6	39·7	39·7	39·8	39·8	39·9	39·9
104	40	40·0	40·1	40·1	40·2	40·2	40·3	40·3	40·4	40·4	40·5

Temperatures on this page have the same sign in both scales.

TABLE VII.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.		Tenths of Degrees.									
Plus.	Minus.	0	1	2	3	4	5	6	7	8	9
105°	41°	40·6	40·6	40·7	40·7	40·8	40·8	40·9	40·9	41·0	41·1
106	42	41·1	41·2	41·2	41·3	41·3	41·4	41·4	41·5	41·6	41·6
107	43	41·7	41·7	41·8	41·8	41·9	41·9	42·0	42·1	42·1	42·2
108	44	42·2	42·3	42·3	42·4	42·4	42·5	42·6	42·6	42·7	42·7
109	45	42·8	42·8	42·9	42·9	43·0	43·1	43·1	43·2	43·2	43·3
110	46	43·3	43·4	43·4	43·5	43·6	43·6	43·7	43·7	43·8	43·8
111	47	43·9	43·9	44·0	44·1	44·1	44·2	44·2	44·3	44·3	44·4
112	48	44·4	44·5	44·6	44·6	44·7	44·7	44·8	44·8	44·9	44·9
113	49	45·0	45·1	45·1	45·2	45·2	45·3	45·3	45·4	45·4	45·5
114	50	45·6	45·6	45·7	45·7	45·8	45·8	45·9	45·9	46·0	46·1
115	51	46·1	46·2	46·2	46·3	46·3	46·4	46·4	46·5	46·6	46·6
116	52	46·7	46·7	46·8	46·8	46·9	46·9	47·0	47·1	47·1	47·2
117	53	47·2	47·3	47·3	47·4	47·4	47·5	47·6	47·6	47·7	47·7
118	54	47·8	47·8	47·9	47·9	48·0	48·1	48·1	48·2	48·2	48·3
119	55	48·3	48·4	48·4	48·5	48·6	48·6	48·7	48·7	48·8	48·8
120	56	48·9	48·9	49·0	49·1	49·1	49·2	49·2	49·3	49·3	49·4
121	57	49·4	49·5	49·6	49·6	49·7	49·7	49·8	49·8	49·9	49·9
122	58	50·0	50·1	50·1	50·2	50·2	50·3	50·3	50·4	50·4	50·5
123	59	50·6	50·6	50·7	50·7	50·8	50·8	50·9	50·9	51·0	51·1
124	60	51·1	51·2	51·2	51·3	51·3	51·4	51·4	51·5	51·6	51·6
125	61	51·7	51·7	51·8	51·8	51·9	51·9	52·0	52·1	52·1	52·2
126	62	52·2	52·3	52·3	52·4	52·4	52·5	52·6	52·6	52·7	52·7
127	63	52·8	52·8	52·9	52·9	53·0	53·1	53·1	53·2	53·2	53·3
128	64	53·3	53·4	53·4	53·5	53·6	53·6	53·7	53·7	53·8	53·8
129	65	53·9	53·9	54·0	54·1	54·1	54·2	54·2	54·3	54·3	54·4
130	66	54·4	54·5	54·6	54·6	54·7	54·7	54·8	54·8	54·9	54·9
131	67	55·0	55·1	55·1	55·2	55·2	55·3	55·3	55·4	55·4	55·5
132	68	55·6	55·6	55·7	55·7	55·8	55·8	55·9	55·9	56·0	56 1
133	69	56·1	56·2	56·2	56·3	56·3	56·4	56·4	56·5	56·6	56·6
134	70	56·7	56·7	56·8	56·8	56·9	56·9	57·0	57·1	57·1	57·2
135	71	57·2	57·3	57·3	57·4	57·4	57·5	57·6	57·6	57·7	57·7
136	72	57·8	57·8	57·9	57·9	58·0	58·1	58·1	58·2	58·2	58·3
137	73	58·3	58·4	58·4	58·5	58·6	58·6	58·7	58·7	58·8	58·8
138	74	58·9	58·9	59·0	59·1	59·1	59·2	59·2	59·3	59·3	59·4
139	75	59·4	59·5	59·6	59·6	59·7	59·7	59·8	59·8	59·9	59·9
140	76	60·0	60·1	60·1	60·2	60·2	60·3	60·3	60·4	60·4	60·5
141	77	60·6	60·6	60·7	60·7	60·8	60·8	60·9	60·9	61·0	61·1
142	78	61·1	61·2	61·2	61·3	61·3	61·4	61·4	61·5	61·6	61·6
143	79	61·7	61·7	61·8	61·8	61·9	61·9	62·0	62·1	62·1	62·2
144	80	62·2	62·3	62·3	62·4	62·4	62·5	62·6	62·6	62·7	62·7

Temperatures on this page have the same sign in both scales.

TABLE VII.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.		Tenths of Degrees.									
Plus.	Minus.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
°	°										
145	81	62·8	62·8	62·9	62·9	63·0	63·1	63·1	63·2	63·2	63·3
146	82	63·3	63·4	63·4	63·5	63·6	63·6	63·7	63·7	63·8	63·8
147	83	63·9	63·9	64·0	64·1	64·1	64·2	64·2	64·3	64·3	64·4
148	84	64·4	64·5	64·6	64·6	64·7	64·7	64·8	64·8	64·9	64·9
149	85	65·0	65·1	65·1	65·2	65·2	65·3	65·3	65·4	65·4	65·5
150	86	65·6	65·6	65·7	65·7	65·8	65·8	65·9	65·9	66·0	66·1
151	87	66·1	66·2	66·2	66·3	66·3	66·4	66·4	66·5	66·6	66·6
152	88	66·7	66·7	66·8	66·8	66·9	66·9	67·0	67·1	67·1	67·2
153	89	67·2	67·3	67·3	67·4	67·4	67·5	67·6	67·6	67·7	67·7
154	90	67·8	67·8	67·9	67·9	68·0	68·1	68·1	68·2	68·2	68·3
155	91	68·3	68·4	68·4	68·5	68·6	68·6	68·7	68·7	68·8	68·8
156	92	68·9	68·9	69·0	69·1	69·1	69·2	69·2	69·3	69·3	69·4
157	93	69·4	69·5	69·6	69·6	69·7	69·7	69·8	69·8	69·9	69·9
158	94	70·0	70·1	70·1	70·2	70·2	70·3	70·3	70·4	70·4	70·5
159	95	70·6	70·6	70·7	70·7	70·8	70·8	70·9	70·9	71·0	71·1
160	96	71·1	71·2	71·2	71·3	71·3	71·4	71·4	71·5	71·6	71·6
161	97	71·7	71·7	71·8	71·8	71·9	71·9	72·0	72·1	72·1	72·2
162	98	72·2	72·3	72·3	72·4	72·4	72·5	72·6	72·6	72·7	72·7
163	99	72·8	72·8	72·9	72·9	73·0	73·1	73·1	73·2	73·2	73·3
164	100	73·3	73·4	73·4	73·5	73·6	73·6	73·7	73·7	73·8	73·8

Temperatures in this Table have the same sign in both scales.

TABLE VIII.—Height Table. Conversion of Metres to Feet.

1 metre = 3·28084 feet.

Metres.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Feet.									
0	0·00	3·28	6·56	9·84	13·12	16·40	19·68	22·97	26·25	29 53
10	32·81	36·09	39·37	42·65	45·93	49·21	52·49	55·77	59·06	62·34
20	65·62	68·90	72·18	75·46	78·74	82·02	85·30	88·58	91·86	95·14
30	98·43	101·71	104·99	108·27	111·55	114·83	118·11	121·39	124·67	127·95
40	131·23	134·51	137·80	141·08	144·36	147·64	150·92	154·20	157·48	160·76
50	164·04	167·32	170·60	173·88	177·17	180·45	183·73	187·01	190·29	193·57
60	196·85	200·13	203·41	206·69	209·97	213·25	216·54	219·82	223·10	226·38
70	229·66	232·94	236·22	239·50	242·78	246·06	249·34	252·62	255·91	259·19
80	262·47	265·75	269·03	272·31	275·59	278·87	282·15	285·43	288·71	291·99
90	295·28	298·56	301·84	305·12	308·40	311·68	315·96	318·24	321·52	324·80
100	328·08	331·36	334·65	337·93	341·21	344·49	347·77	351·05	354·33	357·61
200	656·17	659·44	662·73	666·01	669·29	672·57	675·85	679·13	682·41	685·70
300	984·25	987·53	990·81	994·09	997·38	1000·66	1003·94	1007·22	1010·50	1013·78
400	1312·34	1315·62	1318·90	1322·18	1325·46	1328·74	1332·02	1335·30	1338·58	1341·86
500	1640·42	1643·70	1646·98	1650·26	1653·54	1656·82	1660·11	1663·39	1666·67	1669·95
600	1968·50	1971·78	1975·07	1978·35	1981·63	1984·91	1988·19	1991·47	1994·75	1998·03
700	2296·59	2299·87	2303·15	2306·43	2309·71	2312·99	2316·27	2319·55	2322·83	2326·12
800	2624·67	2627·95	2631·23	2634·51	2637·80	2641·08	2644·36	2647·64	2650·92	2654·20
900	2952·76	2956·04	2959·32	2962·60	2965·88	2969·16	2972·44	2975·72	2979·00	2982·28
1000	3280·84	3284·12	3287·40	3290·68	3293·96	3297·24	3300·53	3303·81	3307·09	3310·37

TABLE IX.—Rainfall Table.

Conversion of Millimetres to English Inches.

Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches
0	0·000	40	1·575	80	3·150	120	4·724	160	6·299	200	7·874
1	0·039	41	1·614	81	3·189	121	4·764	161	6·339	201	7·914
2	0·079	42	1·654	82	3·228	122	4·803	162	6·378	202	7·953
3	0·118	43	1·693	83	3·268	123	4·843	163	6·417	203	7·992
4	0·158	44	1·732	84	3·307	124	4·882	164	6·457	204	8·032
5	0·197	45	1·772	85	3·347	125	4·921	165	6·496	205	8·071
6	0·236	46	1·811	86	3·386	126	4·961	166	6·536	206	8·110
7	0·276	47	1·850	87	3·425	127	5·000	167	6·575	207	8·150
8	0·315	48	1·890	88	3·465	128	5·039	168	6·614	208	8·189
9	0·354	49	1·929	89	3·504	129	5·079	169	6·654	209	8·228
10	0·394	50	1·969	90	3·543	130	5·118	170	6·693	210	8·268
11	0·433	51	2·008	91	3·583	131	5·158	171	6·732	211	8·307
12	0·472	52	2·047	92	3·622	132	5·197	172	6·772	212	8·347
13	0·512	53	2·087	93	3·662	133	5·236	173	6·811	213	8·386
14	0·551	54	2·126	94	3·701	134	5·276	174	6·851	214	8·425
15	0·591	55	2·165	95	3·740	135	5·315	175	6·890	215	8·465
16	0·630	56	2·205	96	3·780	136	5·354	176	6·929	216	8·504
17	0·669	57	2·244	97	3·819	137	5·394	177	6·969	217	8·543
18	0·709	58	2·284	98	3·858	138	5·433	178	7·008	218	8·583
19	0·748	59	2·323	99	3·898	139	5·473	179	7·047	219	8·622
20	0·787	60	2·362	100	3·937	140	5·512	180	7·087	220	8·662
21	0·827	61	2·402	101	3·976	141	5·551	181	7·126	221	8·701
22	0·866	62	2·441	102	4·016	142	5·591	182	7·165	222	8·740
23	0·906	63	2·480	103	4·055	143	5·630	183	7·205	223	8·780
24	0·945	64	2·520	104	4·095	144	5·669	184	7·244	224	8·819
25	0·984	65	2·559	105	4·134	145	5·709	185	7·284	225	8·858
26	1·024	66	2·599	106	4·173	146	5·748	186	7·323	226	8·898
27	1·063	67	2·638	107	4·213	147	5·788	187	7·362	227	8·937
28	1·102	68	2·677	108	4·252	148	5·827	188	7·402	228	8·977
29	1·142	69	2·717	109	4·291	149	5·866	189	7·441	229	9·016
30	1·181	70	2·756	110	4·331	150	5·906	190	7·480	230	9·055
31	1·221	71	2·795	111	4·370	151	5·945	191	7·520	231	9·095
32	1·260	72	2·835	112	4·410	152	5·984	192	7·559	232	9·134
33	1·299	73	2·874	113	4·449	153	6·024	193	7·599	233	9·173
34	1·339	74	2·913	114	4·488	154	6·063	194	7·638	234	9·213
35	1·378	75	2·953	115	4·528	155	6·102	195	7·677	235	9·252
36	1·417	76	2·992	116	4·567	156	6·142	196	7·717	236	9·292
37	1·457	77	3·032	117	4·606	157	6·181	197	7·756	237	9·331
38	1·496	78	3·071	118	4·646	158	6·221	198	7·795	238	9·370
39	1·536	79	3·110	119	4·685	159	6·260	199	7·835	239	9·410
										240	9·449

Tenths of a Millimetre.

Tenths of mm.	1	2	3	4	5	6	7	8	9
Ins.	·004	·008	·012	·016	·020	·024	·028	·032	·035

TABLE X.—Rainfall Table.

Conversion of English Inches and Tenths to Millimetres.

English Inches.	Tenths of an Inch.									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	0·0	2·5	5·1	7·6	10·2	12·7	15·2	17·8	20·3	22·9
1	25·4	27·9	30·5	33·0	35·6	38·1	40·6	43·2	45·7	48·3
2	50·8	53·3	55·9	58·4	61·0	63·5	66·0	68·6	71·1	73·7
3	76·2	78·7	81·3	83·8	86·4	88·9	91·4	94·0	96·5	99·1
4	101·6	104·1	106·7	109·2	111·8	114·3	116·8	119·4	121·9	124·5
5	127·0	129·5	132·1	134·6	137·2	139·7	142·2	144·8	147·3	149·9
6	152·4	154·9	157·5	160·0	162·6	165·1	167·6	170·2	172·7	175·3
7	177·8	180·3	182·9	185·4	188·0	190·5	193·0	195·6	198·1	200·7
8	203·2	205·7	208·3	210·8	213·4	215·9	218·4	221·0	223·5	226·1
9	228·6	231·1	233·7	236·2	238·8	241·3	243·8	246·4	248·9	251·5
10	254·0	256·5	259·1	261·6	264·2	266·7	269·2	271·8	274·3	276·9
11	279·4	281·9	284·5	287·0	289·6	292·1	294·6	297·2	299·7	302·3
12	304·5	307·3	309·9	312·4	315·0	317·5	320·0	322·6	325·1	327·7
13	330·2	332·7	335·3	337·8	340·4	342·9	345·4	348·0	350·5	353·1
14	355·6	358·1	360·7	363·2	365·8	368·3	370·8	373·4	375·9	378·5
15	381·0	383·5	386·1	388·6	391·2	393·7	396·2	398·8	401·3	403·9
16	406·4	408·9	411·5	414·0	416·6	419·1	421·6	424·2	426·7	429·3
17	431·8	434·3	436·9	439·4	442·0	444·5	447·0	449·6	452·1	454·7
18	457·2	459·7	462·3	464·8	467·4	469·9	472·4	475·0	477·5	480·1
19	482·6	485·1	487·7	490·2	492·8	495·3	497·8	500·4	502·9	505·5
20	508·0	510·5	513·1	515·6	518·2	520·7	523·2	525·8	528·3	530·9
21	533·4	535·9	538·5	541·0	543·6	546·1	548·6	551·2	553·7	556·3
22	558·8	561·3	563·9	566·4	569·0	571·5	574·0	576·6	579·1	581·7
23	584·2	586·7	589·3	591·8	594·4	596·9	599·4	602·0	604·5	607·1
24	609·6	612·1	614·7	617·2	619·8	622·3	624·8	627·4	629·9	632·5
25	635·0	637·5	640·1	642·6	645·2	647·7	650·2	652·8	655·3	657·9
26	660·4	662·9	665·5	668·0	670·6	673·1	675·6	678·2	680·7	683·3
27	685·8	688·3	690·9	693·4	696·0	698·5	701·0	703·6	706·1	708·7
28	711·2	713·7	716·3	718·8	721·4	723·9	726·4	729·0	731·5	734·1
29	736·6	739·1	741·7	744·2	746·8	749·3	751·8	754·4	756·9	759·5
30	762·0	764·5	767·1	769·6	772·2	774·7	777·2	779·8	782·3	784·9
31	787·4	789·9	792·5	795·0	797·6	800·1	802·6	805·2	807·7	810·3
32	812·8	815·3	817·9	820·4	823·0	825·5	828·0	830·6	833·1	835·6
33	838·2	840·7	843·3	845·8	848·3	850·9	853·4	856·0	858·5	861·0
34	863·6	866·1	868·7	871·2	873·7	876·3	878·8	881·4	883·9	886·4
35	889·0	891·5	894·1	896·6	899·1	901·7	904·2	906·8	909·3	911·8
36	914·4	916·9	919·5	922·0	924·5	927·1	929·6	932·2	934·7	937·2
37	939·8	942·3	944·9	947·4	949·9	952·5	955·0	957·6	960·1	962·6
38	965·2	967·7	970·3	972·8	975·3	977·9	980·4	983·0	985·5	988·0
39	990·6	993·1	995·7	998·2	1000·7	1003·3	1005·8	1008·4	1010·9	1013·4

Hundredths of an Inch.

Hundredths of an Inch.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mm.	0·25	0·51	0·76	1·02	1·27	1·52	1·78	2·03	2·29

TABLE XI.—Wind Velocity.

Conversion of Statute Miles per Hour into Metres per Second.

1 mile per hour = 0·44704 metres per second.

Miles per Hour.	0	1	2	3	4	5	6	7	8	9
	Metres per Second.									
0	0·0	0·5	0·9	1·3	1·8	2·2	2·7	3·1	3·6	4·0
10	4·5	4·9	5·4	5·8	6·3	6·7	7·2	7·6	8·1	8·5
20	8·9	9·4	9·8	10·3	10·7	11·2	11·6	12·1	12·5	13·0
30	13·4	13·9	14·3	14·8	15·2	15·7	16·1	16·5	17·0	17·4
40	17·9	18·3	18·8	19·2	19·7	20·1	20·6	21·0	21·5	21·9
50	22·4	22·8	23·3	23·7	24·1	24·6	25·0	25·5	26·0	26·4
60	26·8	27·3	27·7	28·2	28·6	29·1	29·5	30·0	30·4	30·9
70	31·3	31·7	32·2	32·6	33·1	33·5	34·0	34·4	34·9	35·3
80	35·8	36·2	36·7	37·1	37·6	38·0	38·4	38·9	39·3	39·8
90	40·2	40·7	41·1	41·6	42·0	42·5	42·9	43·4	43·8	44·3
100	44·7	45·2	45·6	46·0	46·5	46·9	47·4	47·8	48·3	48·7
110	49·2	49·6	50·1	50·5	51·0	51·4	51·9	52·3	52·8	53·2
120	53·6	54·1	54·5	55·0	55·4	55·9	56·3	56·8	57·2	57·7
130	58·1	58·6	59·1	59·5	59·9	60·4	60·8	61·2	61·7	62·1
140	62·5	63·0	63·5	63·9	64·4	64·8	65·3	65·7	66·2	66·6

TABLE XII.—Wind Velocity.

Conversion of Metres per Second to Statute Miles per Hour.

Metres per Second.	Miles per Hour.	Metres per Second.	Miles per Hour.	Metres per Second.	Miles per Hour.	Metres per Second.	Miles per Hour.	Metres per Second.	Miles per Hour.	Metres per Second.	Miles per Hour.
1	2·24	11	24·61	21	46·98	31	69·35	41	91·72	51	114·09
2	4·47	12	26·84	22	49·21	32	71·58	42	93·95	52	116·32
3	6·71	13	29·08	23	51·45	33	73·82	43	96·19	53	118·56
4	8·95	14	31·32	24	53·69	34	76·06	44	98·43	54	120·80
5	11·18	15	33·55	25	55·92	35	78·29	45	100·66	55	123·03
6	13·42	16	35·79	26	58·16	36	80·53	46	102·90	56	125·27
7	15·66	17	38·03	27	60·40	37	82·77	47	105·14	57	127·51
8	17·90	18	40·27	28	62·64	38	85·01	48	107·37	58	129·74
9	20·13	19	42·50	29	64·87	39	87·24	49	109·61	59	131·98
10	22·37	20	44·74	30	67·11	40	89·48	50	111·85	60	134·22

C.—METEOROLOGICAL TABLES ADAPTED FOR THE C.G.S. SYSTEM.

A mercury barometer, unless it be exposed in latitude 45°, and its temperature be at the freezing point of water, *i.e.* 273° A., 0° C., or 32° F., does not give a reading expressed in units based upon the absolute C.G.S. system. It requires correction for temperature and for the difference of latitude from 45°. It is therefore necessary to draw a distinction between the primary reading of the barometer and its ultimate expression in *millibars*, the C.G.S. unit chosen for atmospheric pressure.

In order to make this requirement clear, the mercury barometers adopted by the Meteorological Office are marked as reading **baromils,** and the readings can be corrected for temperature and for latitude by small corrections which are given in the following tables, and thus expressed in **millibars.**

The thermometer attached to the barometer is graduated in the so-called absolute degrees of the centigrade scale, that is to say, the reading is that of a centigrade thermometer increased by 273. This scale is used in spite of the fact that the Fahrenheit scale is still employed at British stations for recording the temperature of the air, because the reading of the attached thermometer is not intended to give the temperature of the air for meteorological purposes, but only to determine the temperature of the mercury column for the purposes of the temperature correction.

The tables are based upon mathematical formulæ similar to those which are set out on pp. 120–123 for British units, and the numbering of the tables has therefore been retained with the addition of an (*a*) in each case.

Humidity.—Tables for the computation of humidity from the readings of the wet and dry bulb are still under consideration; meanwhile a table of Glaisher's factors for the calculation of the depression of the dew point below the dry bulb from the depression of the wet bulb below the dry bulb, which are applicable to any temperature scale, has been included in this section, and the saturation pressure of aqueous vapour for the several temperatures has been given in terms of millibars.

TABLE I (*a*).

Corrections for Temperature for Barometer Readings in Baromils and Temperature on Absolute Scale.

Corrections to be applied to the Readings in Baromils of Mercury Barometers with Brass Scales extending from the Cistern to the top of the Mercurial Column to reduce them to 273° A.

Temperature degrees.	860	880	900	920	940	960	980	1,000	1,020	1,040	1,060	
The corrections for temperatures below 273° are to be added to the reading.												
°		bm.	bm.									°
265	1·1	1·2	1·2	1·2	1·2	1·3	1·3	1·3	1·3	1·4	1·4	265
266	1·0	1·0	1·0	1·1	1·1	1·1	1·1	1·1	1·2	1·2	1·2	266
267	·8	·9	·9	·9	·9	·9	1·0	1·0	1·0	1·0	1·0	267
268	·7	·7	·7	·8	·8	·8	·8	·8	·8	·9	·9	268
269	·6	·6	·6	·6	·6	·6	·6	·7	·7	·7	·7	269
270	·4	·4	·4	·5	·5	·5	·5	·5	·5	·5	·5	270
271	·3	·3	·3	·3	·3	·3	·3	·3	·3	·3	·3	271
272	·1	·1	·1	·2	·2	·2	·2	·2	·2	·2	·2	272
The corrections for temperatures above 273° are to be subtracted.												
273	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	273
274	·1	·1	·1	·2	·2	·2	·2	·2	·2	·2	·2	274
275	·3	·3	·3	·3	·3	·3	·3	·3	·3	·3	·3	275
276	·4	·4	·4	·5	·5	·5	·5	·5	·5	·5	·5	276
277	·6	·6	·6	·6	·6	·6	·6	·7	·7	·7	·7	277
278	·7	·7	·7	·8	·8	·8	·8	·8	·8	·8	·9	278
279	·8	·9	·9	·9	·9	·9	1·0	1·0	1·0	1·0	1·0	279
280	1·0	1·0	1·0	1·1	1·1	1·1	1·1	1·1	1·2	1·2	1·2	280
281	1·1	1·1	1·2	1·2	1·2	1·3	1·3	1·3	1·3	1·4	1·4	281
282	1·3	1·3	1·3	1·4	1·4	1·4	1·4	1·5	1·5	1·5	1·6	282
283	1·4	1·4	1·5	1·5	1·5	1·6	1·6	1·6	1·7	1·7	1·7	283
284	1·5	1·6	1·6	1·7	1·7	1·7	1·8	1·8	1·8	1·9	1·9	284
285	1·7	1·7	1·8	1·8	1·8	1·9	1·9	2·0	2·0	2·0	2·1	285
286	1·8	1·9	1·9	1·9	2·0	2·0	2·1	2·1	2·2	2·2	2·2	286
287	2·0	2·0	2·1	2·1	2·1	2·2	2·2	2·3	2·3	2·4	2·4	287
288	2·1	2·2	2·2	2·2	2·3	2·3	2·4	2·4	2·5	2·5	2·6	288
289	2·2	2·3	2·3	2·4	2·4	2·5	2·6	2·6	2·7	2·7	2·8	289
290	2·4	2·4	2·5	2·5	2·6	2·7	2·7	2·8	2·8	2·9	2·9	290
291	2·5	2·6	2·6	2·7	2·8	2·8	2·9	2·9	3·0	3·0	3·1	291
292	2·7	2·7	2·8	2·8	2·9	3·0	3·0	3·1	3·2	3·2	3·3	292
293	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·3	3·3	3·4	3·5	293
294	2·9	3·0	3·1	3·1	3·2	3·3	3·3	3·4	3·5	3·6	3·6	294
295	3·1	3·2	3·2	3·3	3·4	3·4	3·5	3·6	3·7	3·7	3·8	295
296	3·2	3·3	3·4	3·4	3·5	3·6	3·7	3·7	3·8	3·9	4·0	296
297	3·4	3·4	3·5	3·6	3·7	3·7	3·8	3·9	4·0	4·1	4·1	297
298	3·5	3·6	3·7	3·7	3·8	3·9	4·0	4·1	4·1	4·2	4·3	298
299	3·6	3·7	3·8	3·9	4·0	4·1	4·1	4·2	4·3	4·4	4·5	299
300	3·8	3·9	4·0	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	300
301	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·6	4·7	4·8	301
302	4·1	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	302
303	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	303
304	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	304
305	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	305

TABLE II (*a*).

Reducton of Pressure in Millibars to Mean Sea Level.

Pressure at Station Level, 950 Millibars.

Height in Feet.	Height in Metres	Temperature in Degrees Absolute.						
		250	260	270	280	290	300	310
		Millibars.						
33	10	1·3	1·2	1·2	1·1	1·1	1·0	1·0
66	20	2·6	2·5	2·4	2·3	2·3	2·2	2·1
98	30	3·9	3·8	3·6	3·5	3·3	3·2	3·1
131	40	5·2	5·0	4·8	4·7	4·5	4·4	4·2
164	50	6·6	6·3	6·1	5·8	5·6	5·4	5·2
197	60	7·9	7·5	7·2	7·0	6·7	6·6	6·3
230	70	9·1	8·8	8·5	8·2	7·9	7·6	7·4
262	80	10·5	10·1	9·7	9·3	9·0	8·7	8·5
295	90	11·8	11·3	10·9	10·5	10·2	9·8	9·5
328	100	13·1	12·6	12·2	11·7	11·3	10·9	10·5
361	110	14·4	13·9	13·3	12·8	12·4	12·0	11·6
394	120	15·7	15·1	14·5	14·1	13·6	13·1	12·6
427	130	17·0	16·3	15·8	15·2	14·7	14·2	13·8
459	140	18·3	17·7	17·0	16·3	15·8	15·3	14·8
492	150	19·7	18·9	18·2	17·6	16·9	16·3	15·9
525	160	21·0	20·1	19·4	18·7	18·1	17·5	16·9
558	170	22·3	21·5	20·6	19·9	19·2	18·6	18·0
591	180	23·7	22·7	21·9	21·1	20·3	19·7	19·0
623	190	25·0	23·9	23·1	22·2	21·5	20·8	20·1
656	200	26·3	25·3	24·3	23·5	22·6	21·9	21·2
689	210	27·6	26·5	25·6	24·6	23·8	23·0	22·2
722	220	29·0	27·8	26·8	25·8	24·9	24·0	23·3
755	230	30·3	29·2	28·0	27·0	26·0	25·2	24·3
787	240	31·6	30·4	29·3	28·2	27·2	26·3	25·5
820	250	33·0	31·7	30·5	29·4	28·3	27·4	26·5
853	260	34·4	33·0	31·7	30·6	29·5	28·5	27·6
886	270	35·7	34·3	33·0	31·8	30·7	29·6	28·6
919	280	37·1	35·6	34·2	33·0	31·8	30·8	29·7
951	290	38·4	36·9	35·5	34·2	33·0	31·8	30·8
984	300	39·7	38·2	36·8	35·4	34·1	33·0	31·9
1,017	310	41·0	39·4	38·0	36·6	35·3	34·1	33·0
1,050	320	42·5	40·8	39·2	37·8	36·5	35·2	34·1
1,083	330	43·8	42·1	40·5	39·0	37·6	36·4	35·2
1,116	340	45·1	43·3	41·7	40·2	38·8	37·4	36·2
1,148	350	46·5	44·7	42·9	41·4	40·0	38·6	37·3
1,181	360	47·9	46·0	44·3	42·7	41·1	39·7	38·4
1,214	370	49·2	47·2	45·5	43·8	42·3	40·9	39·5
1,247	380	50·5	48·5	46·7	45·0	43·4	42·0	40·6
1,280	390	52·0	49·9	48·0	46·3	44·7	43·1	41·7
1,312	400	53·3	51·2	49·2	47·4	45·8	44·3	42·8
1,345	410	54·7	52·5	50·5	48·6	46·9	45·4	43·9
1,378	420	56·1	53·9	51·8	49·9	48·2	46·5	44·9
1,411	430	57·5	55·2	53·0	51·1	49·3	47·6	46·1
1,444	440	58·8	56·5	54·3	52·3	50·4	48·7	47·1
1,476	450	60·2	57·9	55·6	53·6	51·7	49·9	48·3
1,509	460	61·6	59·2	56·9	54·8	52·8	51·0	49·3
1,542	470	63·0	60·4	58·1	56·0	54·0	52·2	50·4
1,575	480	64·3	61·8	59·5	57·2	55·2	53·3	51·5
1,608	490	65·7	63·1	60·7	58·4	56·3	54·4	52·6
1,640	500	67·1	64·4	62·0	59·7	57·6	55·6	53·8

TABLE II (*a*).—*continued.*

Reduction of Pressure in Millibars to Mean Sea Level.

Pressure at Station Level, 1,000 Millibars.

Height in Feet.	Height in Metres.	Temperature in Degrees Absolute, 250	260	270	280	290	300	310
		Millibars.						
33	10	1·4	1·3	1·3	1·2	1·2	1·1	1·1
66	20	2·7	2·6	2·5	2·4	2·4	2·3	2·2
98	30	4·1	4·0	3·8	3·7	3·5	3·4	3·3
131	40	5·5	5·3	5·1	4·9	4·7	4·6	4·4
164	50	6·9	6·6	6·4	6·1	5·9	5·7	5·5
197	60	8·3	7·9	7·6	7·4	7·1	6·9	6·6
230	70	9·6	9·3	8·9	8·6	8·3	8·0	7·8
262	80	11·0	10·6	10·2	9·8	9·5	9·2	8·9
295	90	12·4	11·9	11·5	11·1	10·7	10·3	10·0
328	100	13·8	13·3	12·8	12·3	11·9	11·5	11·1
361	110	15·2	14·6	14·0	13·5	13·1	12·6	12·2
394	120	16·5	15·9	15·3	14·8	14·3	13·8	13·3
427	130	17·9	17·2	16·6	16·0	15·5	14·9	14·5
459	140	19·3	18·6	17·9	17·2	16·6	16·1	15·6
492	150	20·7	19·9	19·2	18·5	17·8	17·2	16·7
525	160	22·1	21·2	20·4	19·7	19·0	18·4	17·8
558	170	23·5	22·6	21·7	20·9	20·2	19·6	18·9
591	180	24·9	23·9	23·0	22·2	21·4	20·7	20·0
623	190	26·3	25·2	24·3	23·4	22·6	21·9	21·2
656	200	27·7	26·6	25·6	24·7	23·8	23·0	22·3
689	210	29·1	27·9	26·9	25·9	25·0	24·2	23·4
722	220	30·5	29·3	28·2	27·2	26·2	25·3	24·5
755	230	31·9	30·7	29·5	28·4	27·4	26·5	25·6
787	240	33·3	32·0	30·8	29·7	28·6	27·7	26·8
820	250	34·7	33·4	32·1	30·9	29·8	28·8	27·9
853	260	36·2	34·7	33·4	32·2	31·1	30·0	29·0
886	270	37·6	36·1	34·7	33·5	32·3	31·2	30·1
919	280	39·0	37·5	36·0	34·7	33·5	32·4	31·3
951	290	40·4	38·8	37·4	36·0	34·7	33·5	32·4
984	300	41·8	40·2	38·7	37·3	35·9	34·7	33·6
1,017	310	43·2	41·5	40·0	38·5	37·2	35·9	34·7
1,050	320	44·7	42·9	41·3	39·8	38·4	37·1	35·9
1,083	330	46·1	44·3	42·6	41·1	39·6	38·3	37·0
1,116	340	47·5	45·6	43·9	42·3	40·8	39·4	38·1
1,148	350	48·9	47·0	45·2	43·6	42·1	40·6	39·3
1,181	360	50·4	48·4	46·6	44·9	43·3	41·8	40·4
1,214	370	51·8	49·7	47·9	46·1	44·5	43·0	41·6
1,247	380	53·2	51·1	49·2	47·4	45·7	44·2	42·7
1,280	390	54·7	52·5	50·5	48·7	47·0	45·4	43·9
1,312	400	56·1	53·9	51·8	49·9	48·2	46·6	45·0
1,345	410	57·6	55·3	53·2	51·2	49·4	47·8	46·2
1,378	420	59·0	56·7	54·5	52·5	50·7	48·9	47·3
1,411	430	60·5	58·1	55·8	53·8	51·9	50·1	48·5
1,444	440	61·9	59·5	57·2	55·1	53·1	51·3	49·6
1,476	450	63·4	60·9	58·5	56·4	54·4	52·5	50·8
1,509	460	64·8	62·3	59·9	57·7	55·6	53·7	51·9
1,542	470	66·3	63·6	61·2	58·9	56·8	54·9	53·1
1,575	480	67·7	65·0	62·6	60·2	58·1	56·1	54·2
1,608	490	69·2	66·4	63·9	61·5	59·3	57·3	55·4
1,640	500	70·6	67·8	65·3	62·8	60·6	58·5	56·6

TABLE II (*a*)—*continued.*

Reduction of Pressure in Millibars to Mean Sea Level.

Pressure at Station Level, 1,050 Millibars.

Height in Feet.	Height in Metres.	Temperature in Degrees Absolute,						
		250	260	270	280	290	300	310
					Millibars.			
33	10	1·5	1·4	1·4	1·3	1·3	1·2	1·2
66	20	2·8	2·7	2·6	2·5	2·5	2·4	2·3
98	30	4·3	4·2	4·0	3·9	3·7	3·6	3·5
131	40	5·8	5·6	5·4	5·1	4·9	4·8	4·6
164	50	7·2	6·9	6·7	6·4	6·2	6·0	5·8
197	60	8·7	8·3	8·0	7·8	7·5	7·2	6·9
230	70	10·1	9·8	9·3	9·0	8·7	8·4	8·2
262	80	11·6	11·1	10·7	10·3	10·0	9·7	9·3
295	90	13·0	12·5	12·1	11·7	11·2	10·8	10·5
328	100	14·5	14·0	13·4	12·9	12·5	12·1	11·7
361	110	16·0	15·3	14·7	14·2	13·8	13·2	12·8
394	120	17·3	16·7	16·1	15·5	15·0	14·5	14·0
427	130	18·8	16·1	17·4	16·8	16·3	15·6	15·2
459	140	20·3	19·5	18·8	18·1	17·4	16·9	16·4
492	150	21·7	20·9	20·2	19·4	18·7	18·1	17·5
525	160	23·2	22·3	21·4	20·7	20·0	19·3	18·7
558	170	24·7	23·7	22·8	21·9	21·2	20·6	19·8
591	180	26·1	25·1	24·2	23·3	22·5	21·7	21·0
623	190	27·6	26·5	25·5	24·6	23·7	23·0	22·3
656	200	29·1	27·9	26·9	25·9	25·0	24·2	23·4
689	210	30·6	22·3	28·2	27·2	26·3	25·4	24·6
722	220	32·0	30·8	29·6	28·6	27·5	26·6	25·7
755	230	33·5	32·2	31·0	29·8	28·8	27·8	26·9
787	240	35·0	33·6	32·3	31·2	30·0	29·1	28·1
820	250	36·4	35·1	33·7	32·4	31·3	30·2	29·3
853	260	38·0	36·4	35·1	33·8	32·7	31·5	30·5
886	270	39·5	37·9	36·4	35·2	33·9	32·8	31·6
919	280	41·0	39·4	37·8	36·4	35·2	34·0	32·9
951	290	42·4	40·7	39·3	37·8	36·4	35·2	34·0
984	300	43·9	42·2	40·6	39·2	37·7	36·4	35·3
1,017	310	45·4	43·6	42·0	40·4	39·1	37·7	36·4
1,050	320	46·9	45·0	43·4	41·8	40·3	39·0	37·7
1,083	330	48·4	46·5	44·7	43·2	41·6	40·2	38·9
1,116	340	49·9	47·9	46·1	44·4	42·8	41·4	40·0
1,148	350	51·3	49·4	47·5	45·8	44·2	42·6	41·3
1,181	360	52·9	50·8	48·9	47·1	45·5	43·9	42·4
1,214	370	54·4	52·2	50·3	48·4	46·7	45·2	43·7
1,247	380	55·9	53·7	51·7	49·8	48·0	46·4	44·8
1,280	390	57·4	55·1	53·0	51·1	49·4	47·7	46·1
1,312	400	58·9	56·6	54·4	52·4	50·6	48·9	47·3
1,345	410	60·5	58·1	55·9	53·8	51·9	50·2	48·5
1,378	420	62·0	59·5	57·2	55·1	53·2	51·3	49·7
1,411	430	63·5	61·0	58·6	56·5	54·5	52·6	50·9
1,444	440	65·0	62·5	60·1	57·9	55·8	53·9	52·1
1,476	450	66·6	63·9	61·4	59·2	57·1	55·1	53·3
1,509	460	68·0	65·4	62·9	60·6	58·4	56·4	54·5
1,542	470	69·6	66·8	64·3	61·8	59·6	57·6	55·8
1,575	480	71·1	68·3	65·7	63·2	61·0	58·9	56·9
1,608	490	72·7	69·7	67·1	64·6	62·3	60·2	58·2
1,640	500	74·1	71·2	68·6	65·9	63·6	61·4	59·4

TABLE III (*a*).

Corrections for reducing Barometric Readings in Baromils to Standard Gravity, Latitude 45° (to ·01 *mb.*).

Lat. N. or S.	Correction at 1,000 mb.	Lat. N. or S.	Lat. N. or S.	Correction at 1,000 mb.	Lat. N. or S.	Lat. N. or S.	Correction at 1,000 mb.	Lat. N. or S.
0	2·59	90	16	2·20	74	30	1·30	60
1	2·59	89	17	2·15	73	31	1·22	59
2	2·58	88	18	2·10	72	32	1·14	58
3	2·58	87	19	2·04	71	33	1·05	57
4	2·56	86	20	1·98	70	34	0·97	56
5	2·55	85	21	1·92	69	35	0·89	55
6	2·53	84	22	1·86	68	36	0·80	54
7	2·51	83	23	1·80	67	37	0·71	53
8	2·49	82	24	1·73	66	38	0·63	52
9	2·46	81	25	1·66	65	39	0·54	51
10	2·43	80	26	1·59	64	40	0·45	50
11	2·40	79	27	1·52	63	41	0·36	49
12	2·37	78	28	1·45	62	42	0·27	48
13	2·33	77	29	1·37	61	43	0·18	47
14	2·29	76				44	0·09	46
15	2·24	75				45	0·00	45

The correction is to be subtracted for latitudes 0° to 45°, and to be added for latitudes between 45° and 90°.

TABLE III (*a*).

Corrections for reducing Barometric Readings in Baromils to Standard Gravity, Latitude 45° (to ·1 *mb.*).

Latitude.	Corrections at 950 mb.	Corrections at 1000 mb.	Corrections at 1050 mb.	Latitude.	Corrections at 950 mb.	Corrections at 1000 mb.	Corrections at 1050 mb.	Latitude.	Corrections at 950 mb.	Corrections at 1000 mb.	Corrections at 1050 mb.
°	Millibars.			°	Millibars.			°	Millibars.		
0	−2·5	−2·6	−2·7								
1	2·5	2·6	2·7	31	−1·2	−1·2	−1·3	61	+1·3	+1·4	+1·4
2	2·5	2·6	2·7	32	1·1	1·1	1·2	62	1·4	1·5	1·5
3	2·5	2·6	2·7	33	1·0	1·1	1·1	63	1·4	1·5	1·6
4	2·4	2·6	2·7	34	0·9	1·0	1·0	64	1·5	1·6	1·7
5	2·4	2·6	2·7	35	0·9	0·9	0·9	65	1·6	1·7	1·7
6	2·4	2·5	2·7	36	0·8	0·8	0·8	66	1·6	1·7	1·8
7	2·4	2·5	2·6	37	0·7	0·7	0·7	67	1·7	1·8	1·9
8	2·4	2·5	2·6	38	0·6	0·6	0·7	68	1·8	1·9	2·0
9	2·3	2·5	2·6	39	0·5	0·5	0·6	69	1·8	1·9	2·0
10	2·3	2·4	2·6	40	0·4	0·5	0·5	70	1·9	2·0	2·1
11	2·3	2·4	2·5	41	0·3	0·4	0·4	71	1·9	2·0	2·1
12	2·3	2·4	2·5	42	0·3	0·3	0·3	72	2·0	2·1	2·2
13	2·2	2·3	2·4	43	0·2	0·2	0·2	73	2·0	2·1	2·2
14	2·2	2·3	2·4	44	0·1	0·1	0·1	74	2·1	2·2	2·3
15	2·1	2·2	2·3	45	0·0	0·0	0·0	75	2·1	2·2	2·3
16	2·1	2·2	2·3	46	+0·1	+0·1	+0·1	76	2·2	2·3	2·4
17	2·0	2·1	2·2	47	0·2	0·2	0·2	77	2·2	2·3	2·4
18	2.0	2·1	2·2	48	0·3	0·3	0·3	78	2·3	2·4	2·5
19	1·9	2·0	2·1	49	0·3	0·4	0·4	79	2·3	2·4	2·5
20	1·9	2·0	2·1	50	0·4	0·5	0·5	80	2·3	2·4	2·6
21	1·8	1·9	2·0	51	0·5	0·5	0·6	81	2·3	2·5	2·6
22	1·8	1·9	2·0	52	0·6	0·6	0·7	82	2·4	2·5	2·6
23	1·7	1·8	1·9	53	0·7	0·7	0·7	83	2·4	2·5	2·6
24	1·6	1·7	1·8	54	0·8	0·8	0·8	84	2·4	2·5	2·7
25	1·6	1·7	1·7	55	0·9	0·9	0·9	85	2·4	2·6	2·7
26	1·5	1·6	1·7	56	0·9	1·0	1·0	86	2·4	2·6	2·7
27	1·4	1·5	1·6	57	1·0	1·1	1·1	87	2·5	2·6	2·7
28	1·4	1·5	1·5	58	1·1	1·1	1·2	88	2·5	2·6	2·7
29	1·3	1·4	1·4	59	1·2	1·2	1·3	89	2·5	2·6	2·7
30	1·2	1·3	1·4	60	1·2	1·3	1·4	90	2·5	2·6	2·7

TABLE XIII.—Humidity.

Saturation Pressures with Glaisher's Hygrometric Factors.

Saturation pressures for different temperatures and Glaisher's Hygrometric factors by which the "depression of the wet bulb" must be multiplied in order to give the depression of the dew point below the dry bulb.

Reading of Dry Bulb.		Saturation pressure.	Glaisher's factor.	Reading of Dry Bulb.		Saturation pressure.	Glaisher's factor.
°F	°A 200 +	mb.		°F	°A 200 +	mb.	
10	60·8	2·4	8·78	55	85·8	14·6	1·96
11	61·3	2·4	8·78	56	86·3	15·3	1·94
12	61·9	2·4	8·78	57	86·9	15·9	1·92
13	62·4	2·7	8·77	58	87·4	16·3	1·90
14	63·0	2·7	8·76	59	88·0	17·0	1·89
15	63·6	3·1	8·75	60	88·6	17·6	1·88
16	64·1	3·1	8·70	61	89·1	18·3	1·87
17	64·7	3·1	8·62	62	89·7	19·0	1·86
18	65·2	3·4	8·50	63	90·2	19·7	1·85
19	65·8	3·4	8·34	64	90·8	20·3	1·83
20	66·3	3·7	8·14	65	91·3	21·0	1·82
21	66·9	3·7	7·88	66	91·9	21·7	1·81
22	67·4	4·1	7·60	67	92·4	22·4	1·80
23	68·0	4·1	7·28	68	93·0	23·1	1·79
24	68·6	4·4	6·92	69	93·6	24·1	1·78
25	69·1	4·8	6·53	70	94·1	24·7	1·77
26	69·7	4·8	6·08	71	94·7	25·8	1·76
27	70·2	5·1	5·61	72	95·2	26·8	1·75
28	70·8	5·1	5·12	73	95·8	27·5	1·74
29	71·3	5·4	4·63	74	96·3	28·5	1·73
30	71·9	5·8	4·15	75	96·9	29·5	1·72
31	72·4	5·8	3·70	76	97·4	30·5	1·71
32	73·0	6·1	3·32	77	98·0	31·5	1·70
33	73·6	6·5	3·01	78	98·6	32·5	1·69
34	74·1	6·8	2·77	79	99·1	33·5	1·69
35	74·7	6·8	2·60	80	99·7	34·6	1·68
36	75·2	7·1	2·50	81	100·2	35·9	1·68
37	75·8	7·5	2·42	82	100·8	36·9	1·67
38	76·3	7·8	2·36	83	101·3	38·3	1·67
39	76·9	8·2	2·32	84	101·9	39·6	1·66
40	77·4	8·5	2·29	85	102·4	40·6	1·65
41	78·0	8·8	2·26	86	103·0	42·0	1·65
42	78·6	9·2	2·23	87	103·6	43·3	1·64
43	79·1	9·5	2·20	88	104·1	44·7	1·64
44	79·7	9·8	2·18	89	104·7	46·4	1·63
45	80·2	10·2	2·16	90	105·2	47·8	1·63
46	80·8	10·5	2·14	91	105·8	49·4	1·62
47	81·3	10·9	2·12	92	106·3	50·8	1·62
48	81·9	11·5	2·10	93	106·9	52·5	1·61
49	82·4	11·9	2·08	94	107·4	54·2	1·60
50	83·0	12·2	2·06	95	108·0	55·9	1·60
51	83·6	12·6	2·04	96	108·6	57·6	1·59
52	84·1	13·2	2·02	97	109·1	59·3	1·59
53	84·7	13·6	2·00	98	109·7	61·3	1·58
54	85·2	14·2	1·98	99	110·2	63·0	1·58
				100	110·8	65·0	1·57

D.—TABLES FOR THE CONVERSION OF PRESSURES EXPRESSED IN BRITISH UNITS TO MILLIBARS AND OF TEMPERATURES IN DEGREES ABSOLUTE TO DEGREES FAHRENHEIT.

TABLE IV(*a*). PRESSURE.

The fundamental equations are:—

g_{45} = 980·617 cm./sec.^{2}
density of mercury at normal freezing point of water = 13·5955.
1 mercury inch = 33·8632 millibars.
1 millibar = 0·0295306 mercury inches = 0·750076 mercury millimetres.
using 1 inch = 2·54000 cm.
1 cm. = 0·393701 inch.
and taking the expression "mercury inch" to denote the pressure due to a column of mercury one inch high under standard conditions of temperature (freezing point of water) and gravity (latitude 45°).

VAPOUR PRESSURE. MERCURY INCHES at STANDARD TEMPERATURE (273°A) in LATITUDE 45° to MILLIBARS.

Inches.	0	1	2	3	4	5	6	7	8	9
	Millibars.									
0·0	0·0	0·3	0·7	1·0	1·4	1·7	2·1	2·4	2·7	3·1
0·1	3·4	3·7	4·1	4·4	4·8	5·1	5·4	5·8	6·1	6·5
0·2	6·8	7·1	7·5	7·8	8 2	8·5	8·8	9·2	9·5	9·8
0·3	10·2	10·5	10·9	11·2	11·5	11·9	12·2	12·6	12·9	13·2
0·4	13·6	13·9	14·2	14·6	14·9	15·3	15·6	15·9	16·3	16·6
0·5	17·0	17·3	17·6	18·0	18·3	18·6	19·0	19·3	19·7	20·0
0·6	20·3	20·7	21·0	21·4	21·7	22·0	22·4	22·7	23·1	23·4
0·7	23·7	24·1	24·4	24·7	25·1	25·4	25·8	26·1	26·4	26·8
0·8	27·1	27·5	27·8	28·1	28·5	28·8	29·1	29·5	29·8	30·2
0·9	30·5	30·8	31·2	31·5	31·9	32·2	32·5	32·9	33·2	33·5
1·0	33·9	34·2	34·6	34·9	35·2	35·6	35·9	36·3	36·6	36·9

Inches ..	1	2	3	4	5	6	7	8	9	10
Millibars..	33·9	67·7	101·6	135·5	169·3	203·2	237·0	270·9	304·8	338·6
Inches ..	11	12	13	14	15	16	17	18	19	20
Millibars..	372·5	406·4	440·2	474·1	507·9	541·8	575·7	609·5	643·4	677·3

TABLE IV (*a*)—*continued*.

Equivalents in Millibars of Inches of Mercury at 32° F. and Latitude 45°.

Mercury Inches and Tenths.	0	1	2	3	4	5	6	7	8	9
	Millibars.									
27·0	914·3	914·6	915·0	915·3	915·7	916·0	916·3	916·7	917·0	917·3
27·1	917·7	918·0	918·4	918·7	919·0	919·4	919·7	920·1	920·4	920·7
27·2	921·1	921·4	921·7	922·1	922·4	922·8	923·1	923·4	923·8	924·1
27·3	924·5	924·8	925·1	925·5	925·8	926·1	926·5	926·8	927·2	927·5
27·4	927·8	928·2	928·5	928·8	929·5	929·5	929·9	930·2	930·6	930·9
27·5	931·2	931·6	931·9	932·2	932·6	932·9	933·3	933·6	933·9	934·3
27·6	934·6	935·0	935·3	935·6	936·0	936·3	936·6	937·0	937·3	937·7
27·7	938·0	938·3	938·7	939·0	939·4	939·7	940·0	940·4	940·7	941·0
27·8	941·4	941·7	942·1	942·4	942·7	943·1	943·4	943·8	944·1	944·4
27·9	944·8	945·1	945·4	945·8	946·1	946·5	946·8	947·1	947·5	947·8
28·0	948·2	948·5	948·8	949·2	949·5	949·8	950·2	950·5	950·9	951·2
28·1	951·5	951·9	952·2	952·6	952·9	953·2	953·6	953·9	954·3	954·6
28·2	954·9	955·3	955·6	955·9	956·3	956·6	957·0	957·3	957·6	958·0
28·3	958·3	958·7	959·0	959·3	959·7	960·0	960·3	960·7	961·0	961·4
28·4	961·7	962·0	962·4	962·7	963·1	963·4	963·7	964·1	964·4	964·7
28·5	965·1	965·4	965·8	966·1	966·4	966·8	967·1	967·5	967·8	968·1
28·6	968·5	968·8	969·1	969·5	969·8	970·2	970·5	970·8	971·2	971·5
28·7	971·9	972·2	972·5	972·9	973·2	973·6	973·9	974·2	974·6	974·9
28·8	975·2	975·6	975·9	976·3	976·6	976·9	977·3	977·6	978·0	978·3
28·9	978·6	979·0	979·3	979·6	980·0	980·3	980·7	981·0	931·3	981·7
29·0	982·0	982·4	982·7	933·0	983·4	983·7	984·1	984·4	984·7	985·1
29·1	985·4	985·7	986·1	986·4	986·8	987·1	987·4	987·8	988·1	988·4
29·2	988·8	989·1	989·5	989·8	990·1	990·5	990·8	991·2	991·5	991·8
29·3	992·2	992·5	992·8	993·2	993·5	993·9	994·2	994·5	994·9	995·2
29·4	995·6	995·9	996·2	996·6	996·9	997·2	997·6	997·9	998·3	998·6
29·5	998·9	999·3	999·6	1000·0	1000·3	1000·6	1001·0	1001·3	1001·7	1002·0
29·6	1002·3	1002·7	1003·0	1003·3	1003·7	1004·0	1004·4	1004·7	1005·0	1005·4
29·7	1005·7	1006·1	1006·4	1006·7	1007·1	1007·4	1007·8	1008·1	1008·4	1008·8
29·8	1009·1	1009·4	1009·8	1010·1	1010·5	1010·8	1011·1	1011·5	1011·8	1012·1
29·9	1012·5	1012·8	1013·2	1013·5	1013·8	1014·2	1014·5	1014·9	1015·2	1015·5
30·0	1015·9	1016·2	1016·6	1016·9	1017·2	1017·6	1017·9	1018·3	1018·6	1018·9
30·1	1019·3	1019·6	1019·9	1020·3	1020·6	1021·0	1021·3	1021·6	1022·0	1022·3
30·2	1022·7	1023·0	1023·3	1023·7	1024·0	1024·3	1024·7	1025·0	1025·4	1025·7
30·3	1026·0	1026·4	1026·7	1027·1	1027·4	1027·7	1028·1	1028·4	1028·7	1029·1
30·4	1029·4	1029·8	1030·1	1030·4	1030·8	1031·1	1031·5	1031·8	1032·1	1032·5
30·5	1032·8	1033·2	1033·5	1033·8	1034·2	1034·5	1034·8	1035·2	1035·5	1035·9
30·6	1036·2	1036·5	1036·9	1037·2	1037·6	1037·9	1038·2	1038·6	1038·9	1039·2
30·7	1039·6	1039·9	1040·3	1040·6	1040·9	1041·3	1041·6	1042·0	1042·3	1042·6
30·8	1043·0	1043·3	1043·6	1044·0	1044·3	1044·7	1045·0	1045·3	1045·7	1046·0
30·9	1046·4	1046·7	1047·0	1047·4	1047·7	1048·1	1048·4	1048·7	1049·1	1049·4

TABLE VI (*a*).

CONVERSION of DEGREES ABSOLUTE into DEGREES FAHRENHEIT.

The equations are $A = 273 + \frac{5}{9}(F - 32)$, $F = 32 + \frac{9}{5}(A - 273)$.

Degrees Absolute.	0	1	2	3	4	5	6	7	8	9
	Degrees Fahrenheit.									
250	- 9·4	- 9·2	- 9·0	- 8·9	- 8·7	- 8·5	- 8·3	- 8·1	- 8·0	- 7·8
251	- 7·6	- 7·4	- 7·2	- 7·1	- 6·9	- 6·7	- 6·5	- 6·3	- 6·2	- 6·0
252	- 5·8	- 5·6	- 5·4	- 5·3	- 5·1	- 4·9	- 4·7	- 4·5	- 4·4	- 4·2
253	- 4·0	- 3·8	- 3·6	- 3·5	- 3·3	- 3·1	- 2·9	- 2·7	- 2·6	- 2·4
254	- 2·2	- 2·0	- 1·8	- 1·7	- 1·5	- 1·3	- 1·1	- 0·9	- 0·8	- 0·6
255	- 0·4	- 0·2	0·0	0·1	0·3	0·5	0·7	0·9	1·0	1·2
256	1·4	1·6	1·8	1·9	2·1	2·3	2·5	2·7	2·8	3·0
257	3·2	3·4	3·6	3·7	3·9	4·1	4·3	4·5	4·6	4·8
258	5·0	5·2	5·4	5·5	5·7	5·9	6·1	6·3	6·4	6·6
259	6·8	7·0	7·2	7·3	7·5	7·7	7·9	8·1	8·2	8·4
260	8·6	8·8	9·0	9·1	9·3	9·5	9·7	9·9	10·0	10·2
261	10·4	10·6	10·8	10·9	11·1	11·3	11·5	11·7	11·8	12·0
262	12·2	12·4	12·6	12·7	12·9	13·1	13·3	13·5	13·6	13·8
263	14·0	14·2	14·4	14·5	14·7	14·9	15·1	15·3	15·4	15·6
264	15·8	16·0	16·2	16·3	16·5	16·7	16·9	17·1	17·2	17·4
265	17·6	17·8	18·0	18·1	18·3	18·5	18·7	18·9	19·0	19·2
266	19·4	19·6	19·8	19·9	20·1	20·3	20·5	20·7	20·8	21·0
267	21·2	21·4	21·6	21·7	21·9	22·1	22·3	22·5	22·6	22·8
268	23·0	23·2	23·4	23·5	23·7	23·9	24·1	24·3	24·4	24·6
269	24·8	25·0	25·2	25.3	25·5	25·7	25·9	26·1	26·2	26·4
270	26·6	26·8	27·0	27·1	27·3	27·5	27·7	27·9	28·0	28·2
271	28·4	28·6	28·8	28·9	29·1	29·3	29·5	29·7	29·8	30·0
272	30·2	30·4	30·6	30·7	30·9	31·1	31·3	31·5	31·6	31·8
273	32·0	32·2	32·4	32·5	32·7	32·9	33·1	33·3	33·4	33·6
274	33·8	34·0	34·2	34·3	34·5	34·7	34·9	35·1	35·2	35·4
275	35·6	35·8	36·0	36·1	36·3	36·5	36·7	36·9	37·0	37·2
276	37·4	37·6	37·8	37·9	38·1	38·3	38·5	38·7	38·8	39·0
277	39·2	39·4	39·6	39·7	39·9	40·1	40·3	40·5	40·6	40·8
278	41·0	41·2	41·4	41·5	41·7	41·9	42.1	42·3	42·4	42·6
279	42·8	43·0	43·2	43·3	43·5	43·7	43·9	44·1	44·2	44·4
280	44·6	44·8	45·0	45·1	45·3	45·5	45·7	45·9	46·0	46·2
281	46·4	46·6	46·8	46·9	47·1	47·3	47·5	47 7	47·8	48·0
282	48·2	48·4	48·6	48·7	48·9	49·1	49·3	49·5	49·6	49·8
283	50·0	50·2	50·4	50·5	50·7	50·9	51·1	51·3	51·4	51·6
284	51·8	52·0	52·2	52·3	52·5	52·7	52·9	53·1	53·2	53·4
285	53·6	53·8	54·0	54·1	54·3	54·5	54·7	54·9	55·0	55·2
286	55·4	55·6	55·8	55·9	56·1	56·3	56·5	56·7	56·8	57·0
287	57·2	57·4	57·6	57·7	57·9	58·1	58·3	58·5	58·6	58·8
288	59·0	59·2	59·4	59·5	59·7	59·9	60·1	60·3	60·4	60·6
289	60·8	61·0	61·2	61·3	61·5	61·7	61·9	62·1	62·2	62·4
290	62·6	62·8	63·0	63·1	63·3	63·5	63·7	63·9	64·0	64·2
291	64·4	64·6	64·8	64·9	65·1	65·3	65·5	65·7	65·8	66·0
292	66·2	66·4	66·6	66·7	66·9	67·1	67·3	67·5	67·6	67·8
293	68·0	68·2	68·4	68·5	68·7	68·9	69·1	69·3	69·4	69·6
294	69·8	70·0	70·2	70·3	70·5	70·7	70·9	71·1	71·2	71·4
295	71·6	71·8	72·0	72·1	72·3	72·5	72·7	72·9	73·0	73·2
296	73·4	73·6	73·8	73·9	74·1	74·3	74·5	74·7	74·8	75·0
297	75·2	75·4	75·6	75·7	75·9	76·1	76·3	76·5	76·6	76·8
298	77·0	77·2	77·4	77·5	77·7	77·9	78·1	78·3	78·4	78·6
299	78·8	79·0	79·2	79·3	79·5	79·7	79·9	80·1	80·2	80·4
300	80·6	80·8	81·0	81·1	81·3	81·5	81·7	81·9	82·0	82·2
301	82·4	82·6	82·8	82·9	83·1	83·3	83·5	83·7	83·8	84·0
302	84·2	84·4	84·6	84·7	84·9	85·1	85·3	85·5	85·6	85·8
303	86·0	86·2	86·4	86·5	86·7	86·9	87·1	87·3	87·4	87·6
304	87·8	88·0	88·2	88·3	88·5	88·7	88·9	89·1	89·2	89·4
305	89·6	89·8	90·0	90·1	90·3	90·5	90·7	90·9	91·0	91·2
306	91·4	91·6	91·8	91·9	92·1	92·3	92·5	92·7	92·8	93·0
307	93·2	93·4	93·6	93·7	93·9	64·1	94·3	94·5	94·6	94·8
308	95·0	95·2	95·4	95·5	95·7	95·9	96·1	96·3	96·4	96·6
309	96·8	97·0	97·2	97·3	97·5	97·7	97·9	98·1	98·2	98·4
310	98·6	98·8	99·0	99·1	99·3	99·5	99·7	99·9	100·0	100·2

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